DEPARTMENT OF THE INTERIOR
JOHN BARTON PAYNE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 719

PRELIMINARY REPORT

ON

PETROLEUM IN ALASKA

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

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PREFACE.

By Alfred H. Brooks.

Though petroleum was among the first of the useful minerals found in Alaska, it has received relatively little attention. Except in the Katalla field, all attempts at systematic development were confined to a very brief oil boom that began in 1901 but soon collapsed, owing to the rapid oil developments in California. All the Alaska oil lands were withdrawn in 1910, and patent has been granted to only one claim, which is in the Katalla field. Since then nothing has been done on Alaska petroleum except some drilling in the Katalla field, where productive oil wells have been developed.

This condition persisted until the passage of the recent oil and gas leasing act of February 25, 1920. The provisions of this law applying to Alaska[1] appear to be liberal and will permit prospecting the fairly accessible localities near the Pacific where seepages have been found. These include all the areas that now give promise of being of commercial importance. There are, however, some indications of oil in the extreme northern part of Alaska (pp. 68–70), a region at present almost inaccessible. This region is nearly 1,000 miles from the nearest open port on the Pacific and 500 miles from the nearest point on the Government railroad. Obviously no one could be induced to furnish the capital for developing such a field unless there was promise of very large returns on the enormous investment required. Therefore, before entering upon such a project, capital will demand much more liberal conditions as to size of leaseholds and royalties than are permitted by the present act.

The approval of the oil-leasing law was the signal for starting small stampedes to all the accessible localities where oil seepages were known, and many claims were staked. Later the staking of oil claims was extended into several districts where no indications of oil had been found. Up to September, 1920, 178 applications for oil-leasing permits had been received by the Juneau land office, covering a total of 388,673 acres of land. This by no means includes all the claims that have been staked.

[1] Regulations covering oil and gas permits and leases (including relief measures) and rights of way for oil, gas, and pipe lines: General Land Office Circ. 672, 1920.

As in all oil booms, much the larger part of the land that has been staked will no doubt be found worthless, and there will be many disappointments. Yet, as Mr. Martin shows in this volume, there is good reason to believe that oil fields will be developed in Alaska. On the other hand, the geologic data do not indicate that any startling discoveries will be made. No doubt systematic drilling at localities in Alaska favorable for oil will be begun in 1921.

It is to be expected that with the legitimate enterprises that have for their purpose the search for oil will come the usual flood of stock-jobbing companies that are more energetic in selling stock than in developing an oil field. In the following pages Mr. Martin shows that in certain areas in Alaska there is good chance of finding productive oil pools. In other areas there is some chance of finding oil, though drilling in them must be regarded on present evidence as pure "wildcatting." On the other hand, the geology of much the larger part of Alaska gives no hope that it contains deposits of petroleum.

Those who are inexperienced in oil ventures are warned to be cautious in investing in Alaska oil stock without first obtaining full knowledge as to the character of the company and as to whether its holdings are in the region where petroleum seepages have been found. Wildcatting for oil in some parts of Alaska is perfectly legitimate, but the wildcatter should fully realize that his enterprise is a risky speculation. On account of the adverse local conditions that are set forth in this report, a company searching for oil in Alaska must have more capital than is needed for a similar enterprise in the States.

It is unfortunate that the limits set by the funds available have made it impossible to get complete surveys of the areas in Alaska which are the most promising for possible oil development. Additional surveys of prospective Alaska oil fields are, however, underway and will be continued as fast as the conditions permit. Meanwhile, in view of the wide interest that is now taken in the oil resources of Alaska, this summary of the facts relating to it has been prepared.

Mr. Martin made his first investigation for oil in Alaska in 1903, and since then has from time to time devoted considerable attention to this subject. Other geologists have also made some field investigations bearing on the occurrence of oil in the Territory. The accompanying bibliography shows that the information relating to oil in Alaska is scattered through many publications, some of which are now out of print. This information has been assembled and coordinated by Mr. Martin. In addition to the facts published many others have been obtained from more or less confidential reports furnished by those who have been directly or indirectly connected with the development of oil in Alaska. For material of this kind special acknowledgment is made to Dr. A. M. Bateman, Messrs. J. L.

McPherson, Falcon Joslin, H. R. Harriman, and Capt. M. Manson. By using this material Mr. Martin has been able to present more detailed statements than those contained in the original publications.

In spite of the small developments Alaska has produced some 56,000 barrels of petroleum, all of which was taken from the Katalla field. This oil has found a ready local market. Most of the output made in recent years has been used by a small refinery near Katalla. The large use of petroleum and petroleum products in Alaska is shown by the following table of imports:

Petroleum products shipped to Alaska from other parts of the United States, 1905–1919, in gallons.[a]

Year.	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
1917	23,971,114	3,256,870	750,238	465,693
1918	24,379,566	1,086,852	382,186	362,413
1919	18,784,013	1,007,073	3,515,746	977,703
	237,949,492	23,605,406	11,807,208	3,600,533

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1919, Bureau of Foreign and Domestic Commerce.

PRELIMINARY REPORT ON PETROLEUM IN ALASKA.

By George C. Martin.

INTRODUCTION.

Indications of petroleum have been found in five districts in Alaska (see Pl. I), four of which—the Katalla or Controller Bay field, the Yakataga district, the Iniskin Bay district, on Cook Inlet, and the Cold Bay district, on the Alaska Peninsula—are on the Pacific seaboard, and the fifth, which includes areas near Smith Bay, is on the Arctic coast. The Katalla field, the only one that is now producing oil, could be made tributary to Controller Bay or could be reached from the Copper River Railroad by an easily constructed branch 60 miles long. The Yakataga district is comparatively inaccessible for lack of a harbor. The Iniskin Bay district, on Cook Inlet, and the Cold Bay district, on Alaska Peninsula, are tributary to harbors that are free from ice throughout the year. Smith Bay, which is about 50 miles east of Point Barrow, is a shallow arm of the Arctic Ocean, which is locked in ice for at least 10 months of the year.

The petroleum of the Pacific coast of Alaska, as it is known from wells near Katalla and from seepages in the Yakataga, Iniskin, and Cold Bay districts, is a high-grade refining oil with a paraffin base. The petroleum found near Smith Bay appears to have an asphaltic base.

The oil seepages on Cook Inlet and Alaska Peninsula were apparently known during the period of Russian rule. The oil fields in Alaska began to attract considerable attention in 1896, when claims were staked under the placer law in the Katalla, Yakataga, and Cook Inlet districts. The first well at Katalla was drilled in 1901, and a well was drilled on Cook Inlet at about the same time. There was much activity in the supposed oil fields of Alaska from 1902 to 1904, when many claims were staked in all the fields on the Pacific coast of Alaska, and at other places where oil was supposed to exist, though its existence had not been confirmed. During this period most of the wells in the Katalla, Iniskin, and Cold Bay districts were drilled. This " boom " collapsed in 1904, and all active operations soon ceased. Drilling was stopped for several reasons, among them the failure

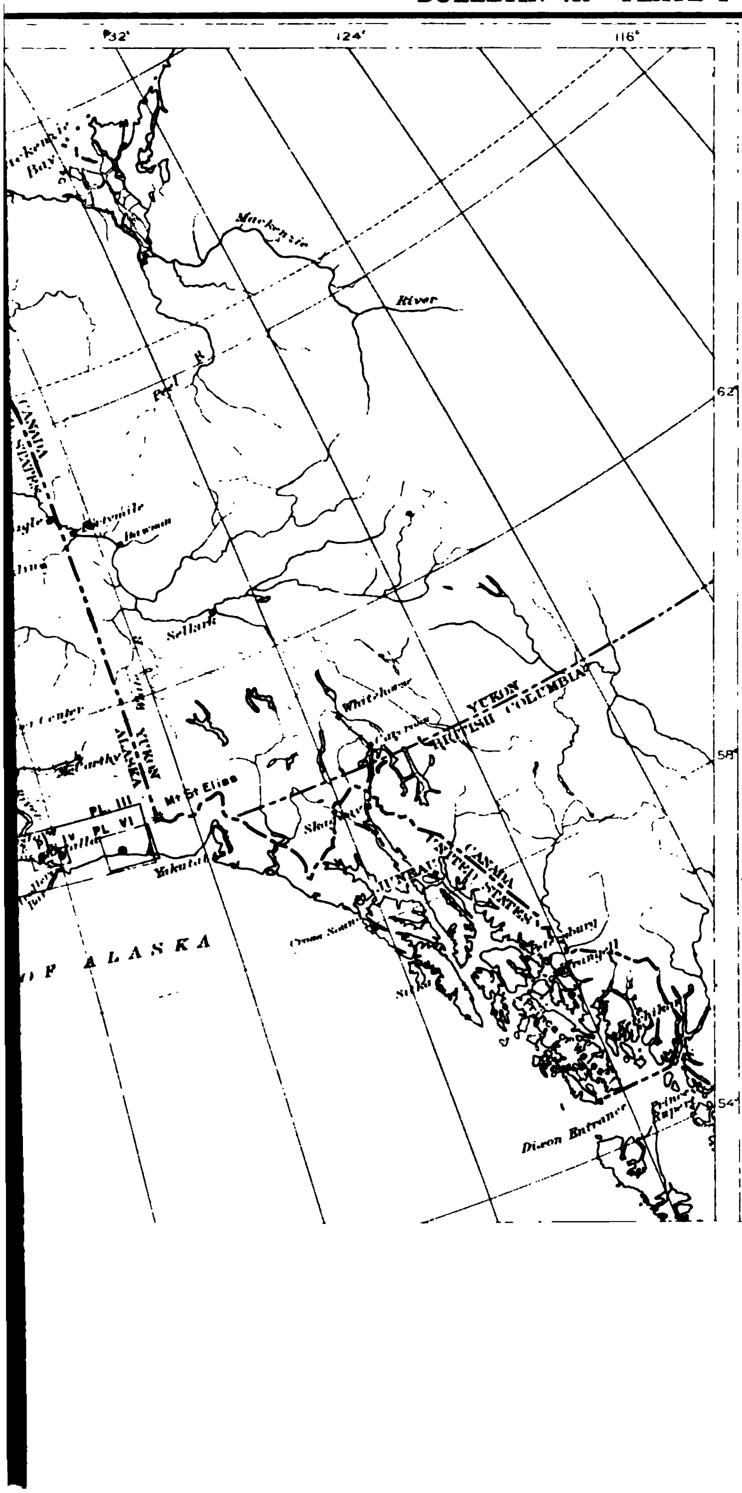
to obtain oil in large quantities, the high cost and great difficul drilling under the peculiarly adverse geographic and geologic ditions existing in Alaska, the increasing supply of fuel oil California, and later of refining oil from the Mid-Continent f and the difficulty of obtaining title to oil lands under the old except by discovery of oil in wells.

All the oil lands in Alaska were withdrawn from entry Nove 3, 1910, but meanwhile patent had been granted to one claim of acres in the Katalla field, and other claims were pending, on son which oil seems to have been discovered. Assessment work has continued on some of the claims that were staked before the w drawal, especially in the Katalla field, and applications for pat have been made. Other claimants have doubtless acquired p rights under section 22 of the new leasing law.

Drilling has been done only in the Katalla, Iniskin, and Cold fields. About 40 wells, aggregating in depth about 35,000 feet, h been drilled, 31 of which, aggregating 28,431 feet, are in the Kat field. Oil has been produced commercially only in the Katalla fi which has yielded since 1904 about 56,000 barrels of crude oil for as local fuel and for distillation in a small local refinery that been operated since 1912.

It is too early to forecast the possible ultimate extent of the Ala petroleum industry, but some conclusions as to its probable fut may nevertheless be given. The conditions in each field are discus in greater detail farther on, but a summary of the conclusions be given here.

The geologic conditions in the Katalla field are by no means couraging, and none of the 31 wells have yielded a large output, the field has produced oil commercially for nearly 10 years, and large proportion of the better-located wells have been producti The results of drilling have on the whole been rather consistent a have proved the existence of moderate amounts of oil in at least part of the district, especially within the area of the patented clai The wells outside this claim are not numerous enough to determi the outlines of the productive areas or even to show whether exists in sufficient quantity to pay for exploitation. The widespre and copious seepages indicate that large areas may be regarded possible oil land. The results obtained in the wells on the patent claim near Katalla probably give a fair indication of what may expected near the other seepages. A large proportion of any ne wells that may be drilled near these seepages will probably yiel small quantities of oil, and some of them may be larger producer but there is no reason to expect more favorable results at any speci localities or at greater depths.


132°
124°
116°
62°
58°
54°
Bay
Mackenzie
River
Peel R
CANADA
Dawson
Selkirk
Whitehorse
YUKON
BRITISH COLUMBIA
YUKON
ALASKA
Mt St Elias
PL. III
PL. V
PL. VI
Yakutat
Skagway
Juneau
CANADA
UNITED STATES
Sitka
Wrangell
Ketchikan
Dixon Entrance
Prince Rupert
ALASKA

The geologic structure in the Yakataga district has been described as more regular than that in the Katalla field, but this seeming regularity is possibly due to the fact that a narrower section is exposed. The structure may be similar to that in the eastern part of the Bering River coal field, where the more massive and best exposed beds seemingly indicate regular structure but where the softer and less conspicuous beds show intricate folding, and where the folding has in places really been so close that many of the minor folds have been partly flattened out. The seepages in the Yakataga district are numerous and yield a large volume of oil. The Yakataga district is certainly worth testing with the drill, provided the difficulties of landing supplies and of shipping oil can be overcome, but there is doubt as to whether it is any more promising than the Katalla field.

The possible oil fields on Cook Inlet have not been adequately tested with the drill, but the stratigraphy, structure, and seepages indicate that some oil will probably be obtained, most likely along the easternmost anticline and belt of seepages in the peninsula between Iniskin and Chinitna bays. Favorable localities may be sought elsewhere within the areas of Jurassic rocks, but the larger part of these areas is less promising because of steep dips or of the profound depth of the probable oil sands or of difficulty of access.

The Alaska Peninsula has possibilities as an oil field. In parts of the Cold Bay district the stratigraphy, the structure, and the seepages give promise of future production. The few wells drilled near Cold Bay give no adequate test of any part of the field. Most of the Alaska Peninsula is unexplored, and possibly the most favorable localities for drilling have not yet been found.

In northern Alaska oil may be present in a wide area, but the difficulties of transportation and the very short open season make it doubtful whether commercial development is feasible at this time.

Future discoveries may reveal indications of petroleum in other parts of Alaska, but no localities are now known where drilling is warranted except in the regions described above.

KATALLA OR CONTROLLER BAY OIL FIELD.

LOCATION.

The Katalla or Controller Bay oil field is on the Pacific coast of Alaska near latitude 60° 10′ N., longitude 144° 20′ W. The localities at which there are known indications of petroleum are confined to a belt that is about 25 miles long (from east to west) and 4 to 8 miles wide (from north to south). (See Pl. IV.) This belt is bounded on the north in part by the Bering River coal field, on the south by Controller Bay, the Pacific Ocean, and the alluvial flats on the east shore of Controller Bay, on the east by Bering Glacier, and on the west by Copper Delta.

Katalla, the distributing point for the oil field, is a small settlement about six days' sail from Seattle and about 50 miles in an air line east of Cordova. Katalla can be reached either by direct landing from Seattle steamers or by launches from Cordova. Passengers and freight are landed at Katalla by means of scows and launches when the wind is favorable. During the period of excitement resulting from the discovery of oil some use was made of Controller Bay, 15 miles east of Katalla. Within its shelter ships discharged on scows, which were landed at Katalla or at the mouth of Bering River. Plans have been formulated for developing the Bering coal field by building a branch from the Copper River Railroad to connect with tidewater at Cordova, on Prince William Sound. (See Pl. III.) Another plan contemplates the building of a railway from a terminal on Controller Bay. Either plan could be made to serve the Katalla oil field with but little additional expense. Controller Bay could also be used as a shipping point for petroleum without a railroad by building short pipe lines to tidewater. The available timber is ample for construction. Fuel and blacksmith coal can be obtained in the Bering River coal field, which is only a few miles north of the oil field.

Passengers and freight are carried from Katalla to all parts of Controller Bay and to Bering Lake by launches, and much of the rest of the region is accessible by canoes. Bering River as far as the mouth of Canyon Creek, Gandil, Nichawak, and Katalla rivers, and other large streams are navigable for canoes and poling boats, which carry most of the local freight and passengers.

Land travel is practicable only where trails have been built, because the vegetation is dense, the flats are swampy, and the streams are numerous and many of them are hard to cross. Most of the trails are indicated on Plate IV. The trails that are most used are those from Katalla to Mirror Slough, from Katalla along the beach to Strawberry Harbor and to the head of Katalla Slough, and from the mouth of Bering River to the head of Katalla Slough. The last is a well-built wagon road. Other shorter trails reach practically all the camps that are not accessible by water. Short tramroads have been built from the head of Katalla Slough and from the mouth of Redwood Creek to neighboring oil wells. Telephone lines are in operation from Katalla to Cordova, where they connect with the Government cable and wireless systems, and to some of the local coal and oil camps.

SURVEYS AND INVESTIGATIONS.

Geologic reconnaissance surveys of the Katalla oil fields were made
r in 1903 and 1904, and detailed topographic surveys were
r the more promising part of the field in 1905. Detailed

OIL WELLS NEAR KATALLA.

Numbers correspond to those in text and on figure 1.

geologic surveys were made in 1905 and 1906. The reports on these surveys have already been published [2] but are no longer available for free distribution. The information herein presented is based chiefly upon these surveys and upon supplemental investigations made by the writer in 1917. The detailed topographic map [3] of the region can still be obtained on application to the Geological Survey.

DEVELOPMENT.

The seepages near Katalla became known about 1896. The first well, known as well A, on the banks of Oil Creek, on claim No. 1,[4] now patented, was drilled in 1901 by an English company known by different names and operating under lease from the Alaska Development Co. This well [5] was drilled to a depth of 270 feet and was abandoned because of the loss of the tools, without obtaining any oil.

In 1902 the lessees of the Alaska Development Co. drilled well No. 1 to a depth of 366 feet and obtained a flow of oil.

In 1903 the lessees of the Alaska Development Co. deepened well No. 1 to 550 feet without obtaining additional oil and drilled well No. 2 on the same claim, obtaining some oil; the Alaska Petroleum & Coal Co. drilled its first well (No. 110) near the head of Katalla Slough and its second well (No. 111) on Katalla River without obtaining any oil; and another company began a well (No. 102) on the east bank of Bering River.

In 1904 the lessees of the Alaska Development Co. drilled well No. 3 and well B and erected a derrick for well C and possibly drilled it, all on claim No. 1. (See fig. 1.) Some oil was obtained in well No. 3. The same company drilled a well (No. 108, Pl. IV) on Redwood No. 11 claim, a well (No. 103) on the bank of Chilkat Creek, on Chilkat No. 10 claim, two wells (Nos. 104 and 105) on Chilkat No. 11 claim, along the wagon road west of Chilkat Creek, and erected a derrick but did not drill on Barrett No. 1 claim, a mile west of Burls Creek. Some oil was obtained in the well on the Redwood claim, and in one or both of the wells on Chilkat No. 11 claim. One or more of the wells on claim No. 1 were pumped to supply fuel for use at the wells that

[2] Martin, G. C., Petroleum fields of Alaska and the Bering River coal fields: U. S. Geol. Survey Bull. 225, pp. 365–382, 1904; The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, 64 pp., 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 128–139, 1905; Petroleum at Controller Bay: U. S. Geol. Survey Bull. 314, pp. 89–103, 1907; Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, 141 pp., 1908.

[3] Topographic map of Controller Bay region, Alaska (No. 601A); scale 1:62,500; by E. G. Hamilton and W. R. Hill. Price, 35 cents retail or 21 cents wholesale.

[4] For the positions of the wells see Pl. IV and fig. 1, where they are indicated by the numbers here given.

[5] Further information concerning each well is given on pp. 21–25.

were being drilled. The Alaska Petroleum & Coal Co. drilled third well (No. 112) near Katalla but obtained no oil. Two w (Nos. 106 and 107) were drilled on Strawberry Harbor by Clar Cunningham, but no oil was obtained.

In 1905 the lessees of the Alaska Development Co. did no dril and their wells were not pumped. The Alaska Petroleum & C Co. drilled its fourth well (No. 113) near Katalla, and the so-ca Rathbun well (No. 101) was drilled on the west shore of Be Lake.

In 1906 drilling was continued at the two wells begun in 1905, no oil was obtained. Patent was granted for claim No. 1 of Alaska Development Co.

In 1907 the Alaska Petroleum & Coal Co. drilled its fifth well (114). Two wells on the patented claim were pumped to supply for use in local railroad construction.

In 1908 and 1909 no wells were drilled. Some oil was pumped local use in 1908 from the wells on the patented claim.

In 1910 the Amalgamated Development Co. obtained control the patented claim and of the rights and other property of Alaska Development Co. The wells previously drilled by the less of the Alaska Development Co. were cleaned out and tanks and pipe line were built. All oil lands in Alaska were withdrawn fr entry November 3, 1910.

In 1911 a well (No. 115) was drilled by the Alaska Coal Oil Co. Mirror Slough, which is said to have struck some oil and gas at depth of 700 feet. Derricks were probably erected about this ti at other localities, but it is not known that any further drilling w done. Preparations were made for utilizing oil from the wells the patented claim, a small experimental refinery was built on Katal Slough, and possibly some oil was pumped or refined.

In 1912 four wells (Nos. 4, 5, 6, and 7) were drilled on the patent claim. Oil was obtained in wells 4, 5, and 7. The refinery w placed in regular operation and supplied gasoline and other produc for local use. Drilling was continued at the well (No. 115) Mirror Slough in 1912 and for some time thereafter.

In 1913 well No. 8 was drilled on the patented claim, the old wells on this claim were pumped, and the refinery was operated.

In 1914 and 1915 the refinery was operated, but no new drillin was undertaken. In 1915 the company that had been operating th refinery went into the hands of a receiver.

In 1916 the patented claim and the refinery were bought by th St. Elias Oil Co. Production was increased somewhat by cleanin out the old wells, but no new wells were drilled.


5 Miles
OIL FIE

In 1917 the St. Elias Oil Co. drilled well No. 9 on the patented claim and well No. 10 (same as No. 109, Pl. IV) on Redwood No. 12 claim. The refinery was operated as usual. The Alaska Coal Oil Co. continued its efforts to shut off the water and recover the oil in its well on Mirror Slough. Some of the pending claims were surveyed preparatory to application for patent.

In 1916 two productive wells (Nos. 11 and 12) were drilled on the patented claim and well No. 13 was begun.

In 1919 well No. 13 was finished and well No. 14, also on the patented claim, was drilled to a depth of 1,410 feet.

From 1901 to 1919, inclusive, 31 wells have been drilled in the Katalla field. On the patented claim (see Pl. II) 16 wells have been drilled to depths of 200 to 1,810 feet. Oil was obtained in 10 wells (Nos. 1, 2, 3, 4, 5, 7, 8, 11, 12, and 13), of which Nos. 8 and 2 ceased to be pumped in 1907 and 1919, respectively. Three wells (Nos. A, C, and 6) were abandoned at shallow depths because of accidents. Two wells (Nos. B and 9) should be classed as dry holes, and one well (No. 14) has not yielded any oil but is not yet finished. On the claims formerly held by the Alaska Development Co. between the patented claim and the mouth of Bering River 5 wells (Nos. 103, 104, 105, 108, and 109, Pl. IV) have been drilled. The well on Redwood No. 11 claim (No. 108) and one of the wells (No. 105) on Chilkat No. 11 claim are probable producers. There is some oil and gas in the other well (No. 104) on Chilkat No. 11 claim. The well (No. 103) on Chilkat No. 10 claim was probably abandoned at a shallow depth because of accident. The well (No. 109) on Redwood No. 12 claim is nonproductive. The remaining 10 wells were drilled by five companies in various parts of the field. Three of them (No. 111 on Katalla River, No. 106 on Strawberry Harbor, and No. 102 on Bering River) are situated on the mud flats and were abandoned without reaching bedrock. The well on Mirror Slough (No. 115), which has encountered some oil and gas, is not regarded by the owners as finished. The remaining six wells (Nos. 101, 107, 110, 112, 113, and 114) are all nonproductive and were abandoned at various depths down to 1,710 feet. Descriptions of the wells are given on pages 21–25. The total petroleum output of the Katalla field from 1904 to the end of 1919 is believed to be about 56,000 barrels, valued at about $270,000.

Casing-head gas is obtained from most of the productive wells on the patented claim. It is used for power and domestic heat and light at the oil camp. The quantity of gas is probably in excess of these needs, but no further use is now feasible because of the lack of a local market.

GEOLOGY.

GENERAL FEATURES.

In the Controller Bay region (see Pl. IV) there are some igneous and metamorphic rocks probably of pre-Tertiary age, a great thickness of thoroughly consolidated and highly folded Tertiary sedimentary rocks, which include the oil-bearing strata, and a large area and great thickness of Quaternary alluvial deposits. The general succession of rocks in the Controller Bay region, including both the Katalla oil field and the adjacent Bering River coal field, is shown in the following table:

General section of rocks of the Controller Bay region.

Age.	Formation.	Character of rocks.	Thickness.
Quaternary.		Stream deposits, probably in part underlain by marine sediments. Sediments and abandoned beaches of glacial lakes. Morainal deposits. Marine silt and clay.	*Feet.* 0-500± 0-200± 0-100± 100
Tertiary or later.		Diabase and basalt dikes.	
Tertiary.	Tokun formation.	Sandstone. Shale.	500 2,000+
	Kushtaka formation.	Arkose with many coal beds.	2,500±
	Stillwater formation.	Shale and sandstone.	1,000±
	Katalla formation.[a]	Conglomerates, and sandstones and shales, some of which are conglomeratic. Sandstone. Shale, concretionary and with a glauconitic bed at the base. Sandstone. Shale.	2,500 500 2,000 1,000 500+
Pre-Tertiary.		Graywacke, slates, and igneous rocks.	

[a] The position of the Katalla formation with reference to the other Tertiary formations is not definitely established.

PRE-TERTIARY ROCKS.

The metamorphic rocks of the Controller Bay region crop out in two areas. One of these areas covers all of Wingham Island except its narrow southeastern point, and the other is west of Katalla, in Ragged Mountain. The rocks consist of black slates having well-developed cleavage, graywacke, chert, a variety of highly colored fine-grained rocks of uncertain origin, and greenstone and other igneous rocks, which probably include both bedded and intrusive masses.

The observed contacts with the Tertiary rocks are faults, and these rocks are probably in both areas overthrust upon the Tertiary sediments.

TERTIARY ROCKS.

Most of the consolidated rocks of the Katalla oil field have been included in the Katalla formation, which occupies the hilly area south of Bering Lake between Bering and Katalla rivers and the low hills between the base of the steep eastern slope of Ragged Mountain and Katalla River. Rocks that are probably, in part at least, equivalent to these crop out in Gandil Mountain, Nichawak Mountain, Mount Campbell, and the neighboring small hills of the Nichawak region, on Kayak Island and on the southeastern point of Wingham Island, in the low hills west of Bering Lake, possibly in parts of the region north and northeast of Bering Lake, and in the low hills between Ragged Mountain and the mouth of Copper River.

The Katalla formation is composed of shales, sandstones, and conglomerates. The section has not been definitely established but seems to be as follows:

Generalized section of Katalla formation in hills south of Bering Lake.

	Feet.
Conglomerate and conglomeratic sandstone interbedded with shale and sandstone	2,500
Flaggy sandstone	500±
Soft shale with calcareous concretions and with bed of glauconitic sand near base	2,000
Sandstone	1,000
Soft shale	500+

The shales that constitute the bulk of the formation are soft, dark, and argillaceous, in places with many limestone concretions and with at least one bed of glauconitic sand.

The formation seems to include two massive and prominent beds of sandstone. One of these overlies the thickest and most prominent bed of shale; the other underlies the same bed and is in turn underlain by a bed of shale that resembles the thicker shale above it. It is possible, however, that the beds are duplicated by faulting and that the supposed lower sandstone and shale are a repetition of the sandstone and shale above.

The upper sandstone is overlain by conglomerates, sandstones, and shales, apparently of great thickness. The conglomerates, though massive, are irregular in extent and position and grade locally into pebbly sandstone or shale or into rock containing no pebbles. The more typical of the conglomerates contain usually well-rounded but

unsorted pebbles and boulders of granite, greenstone, gneiss, and other rocks and minerals. The material making up the conglomerate ranges in size from that of very coarse sand to that of large boulders, but most of it is less than 6 inches in diameter. The boulders examined show no glacial facets or scratches. The matrix consists of fine shale, sandstone, and arkose.

The Katalla formation contains numerous poorly preserved fossils, which are clearly Tertiary but which do not indicate with certainty any precise horizon within the Tertiary, though they are probably Miocene. The paleontologic evidence of the age of the Katalla formation that was gathered when the detailed survey of the region was made has already been published.[a] The only additional evidence was obtained from a small lot of fossils contained in a boulder, probably derived from the Katalla formation, which the writer found in the bed of Redwood Creek in 1917 and on which W. H. Dall has reported as follows:

> The shells (contained in the fragments of a concretion) are all of one species of *Pseudamusium*, namely, *P. peckhami* Gabb, of the Miocene Monterey horizon. They appear to be identical with California specimens.

The rocks on the shore of Mirror Slough consist chiefly of graywacke or highly indurated arkosic sandstone interbedded with some shale or slate. Most of the observed exposures consist of graywacke or arkose. This may mean either that the graywacke or arkose is the dominant rock in the area or that, being more resistant than the argillaceous beds, it makes most of the outcrops. These rocks, in the writer's opinion, were originally not unlike the more sandy beds of the Katalla formation and may possibly be correlated with them. They differ from those beds chiefly in being slightly more metamorphosed. They are also not unlike some of the less metamorphosed graywackes of the Orca and Valdez groups of Prince William Sound. No evidence of the age of these rocks has been obtained, except from several small lots of fossil plants collected by the writer in 1917 from exposures of arkose and argillite near the mouth of Mirror Slough. F. H. Knowlton has submitted the following statement concerning these fossils:

> This material includes about a dozen pieces of hard arkosic matrix exhibiting only pieces of bark, fragments apparently of monocotyledonous stems, and fragments of some grasslike leaves. The question to be decided is whether this material is Mesozoic or Tertiary in age. It is absolutely impossible to decide this point with certainty, but from the resemblance of the grass leaves to many I have seen from the Kenai formation I might hazard the guess—it can hardly be more—that it is probably Tertiary. If it belong in the Mesozoic at all I should presume it to be late Mesozoic. I must add that very little weight should be attached to this report.

G. C., Geology and mineral resources of the Controller Bay region, Alaska: urvey Bull. 335, pp. 28–30, 38–41, 1908.

Several small basalt or diabase dikes have been found in the hills south of Bering Lake. A diabase dike on the crest of the hill between Katalla River and Clear Creek is about 20 feet wide and several hundred feet long. It is the largest dike seen in the Tertiary rocks of the mainland.

QUATERNARY DEPOSITS.

The east shore of Bering River and of Controller Bay from the margin of Bering Glacier to the ocean is a flat plain of mud, sand, and gravel, which is constantly growing by the addition of sediment deposited by glacial streams along their courses and at their mouths. Nichawak Mountain, Mount Campbell, Gandil Mountain, and the Suckling Hills rise like islands from this plain, and a very short time ago they were islands in an older extension of Controller Bay that has been filled by the sediment of these glacial streams. These fluviatile deposits cover large areas in the Copper River delta, which extends into the west end of the district here described. The valley of Katalla River and of the streams that head near it and flow into Bering Lake is floored with similar material, as are also the lower courses of most of the other streams that enter Controller Bay. These unconsolidated deposits, some of which are of fluviatile origin, are known from well borings (see pp. 24–25) to have a thickness of more than 580 feet at one point on Bering River and of more than 280 feet in the Katalla Valley.

The beaches, bars, and islands which the ocean waves are building along these shores are composed largely of reworked fluviatile and glacial material and are in part contemporaneous with the stream deposits. They include Okalee Spit, Kanak Island, the beach from Strawberry Point to Katalla, Softuk Bar, and the long line of islands that extend across the front of the Copper River delta.

STRUCTURE.

The rocks of the Controller Bay region are much folded and in some places faulted. They have a general northeast strike and a northwest dip, but the strike and dip vary sharply and irregularly from place to place, the rocks having evidently been involved in violent crustal movements. Though the structure in areas of uniform monoclinal dip appears at first to be simple, a closer study shows that much of the simplicity is only apparent and that the structure is extremely complex. The problems involved are difficult, and it must be admitted not only that our present knowledge of the structural details in most of the area is incomplete and unsatisfactory but that even the broader scheme of the structure is not definitely

known. Numerous faults were noted and there are doubtless others, and faulting has probably played a large part in the development of the structure.

The peninsula south of Bering Lake shows considerable diversity of structure. In the region east of Burls Creek the strike is north and northeast and the dips are both east and west. An anticline extends along the canyon of Chilkat Creek, and its western flank is broken by a fault. East of this anticline there are several minor folds, the most noticeable being a closely compressed syncline, which extends diagonally across the south end of the ridge east of Chilkat Creek and is shown on the map by the position of a belt of sandstone. The west bank of Bering River in its lower course is probably on the line of a fault.

The valley of Burls Creek and the hills northeast of it contain several folds, which are revealed by the sinuous boundary of the shale and sandstone. These folds descend into the valley of Burls Creek and die out or are cut off by a fault along the steep western side of the valley.

On the hills between Burls and Redwood creeks an anticline extends northeastward through the headwaters of Split Creek. North of this anticline is a spoon-shaped syncline, which is separated from the anticline by a fault. South of the anticline the monoclinal southerly dip continues to the edge of the flats bordering Controller Bay. The structure of this area is shown on Plate IV. Possibly the valley of the upper east fork of Redwood Creek contains a fault that has caused a repetition of the shales and sandstones. If this fault exists, the shale in the valley of Split Creek is the same as that on the headwaters of Redwood Creek, and the sandstone on the ridge north of Redwood Creek is the same as the sandstone underlying the conglomerate on the ridge south of it. Another possibility is that the upper valley of Redwood Creek and the ridge north of it each contain a closely compressed and overturned anticline and syncline which would cause a repetition of the beds similar to that which would be made by faulting. The shales and sandstones are near enough alike to admit of this possibility, but the fault or folds have not been found, and the presence of two shales and two sandstones is indicated in other localities.

The fact that the sandstones and conglomerates east of Redwood Creek are not found west of it indicates that a large fault extends along the course of the creek. At the south end of the range of hills between Redwood Creek and Katalla River there is an irregular syncline, and immediately west of it there are several small, closely compressed folds.

An anticline possibly lies southeast of this fold extending southwestward from a point near the oil drillers' camp at Redwood, where

it is probably cut off by the Redwood Creek fault to a point near the head of Katalla Slough. The north end of the ridge west of Redwood Creek has a monoclinal southeasterly dip.

The rocks of the crescent-shaped hill that extends from Cave Point to Point Hey have a curving strike parallel to the crest of the hill and a dip toward its concave seaward face. This appears to be the end of a seaward-pitching syncline, of which only the nose remains above the ocean.

The rocks between Katalla River and the base of the steep eastern slope of Ragged Mountain have a general northeast strike and a diversity of dips which have not been interpreted. The base of the steep mountain slope mentioned above lies on the line of contact between the Katalla formation and the metamorphic rocks. The latter strike east, have steep and diverse dips, and are considered to be overthrust upon the younger shales of the Katalla formation.

PETROLEUM.

WELLS.

Oil has been obtained in 12 or 14 of the 31 wells that have been drilled in the Katalla field (see pp. 21–25), 10 of which have produced it in commercial quantities. Seven of these 31 wells were abandoned at shallow depths and 10 or 12 were nonproductive. Most of the systematic search for petroleum has been made within the small area (151 acres) of the single patented claim (see Pl. II), where there are 16 wells, which include all that have been pumped and most of those that have encountered oil. About 28,431 feet of drilling has been done in the field, 13,308 feet of which was on the patented claim. The 31 wells in the field range in depth from 100 to 1,810 feet and average 917 feet; the 12 productive wells range in depth from 366 to 1,130 feet and average 885 feet. Neither the field as a whole nor any part of it, except possibly the patented claim, has been adequately tested with the drill.

In the following account of the wells drilled in the district the numbers and letters by which the wells are designated correspond to numbers and letters on Plate IV and figure 1, showing the geographic positions of these wells. (See also Pl. II.)

No. A. Near head of Katalla Slough. Drilled in 1901 to a depth of 270 feet[1] and abandoned because of loss of tools, without producing oil, although it has been stated[2] that some oil was found.

No. 1. Near head of Katalla Slough. Drilled in 1902 to a depth of 366 feet, where a flow of oil was obtained. Drilled to 550 feet in 1903, without further

[1] Oliphant, F. H., The production of petroleum in 1901: U. S. Geol. Survey Mineral Resources, 1901, p. 208, 1902 (not in bound volume).

[2] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1903 p. 691, 1904.

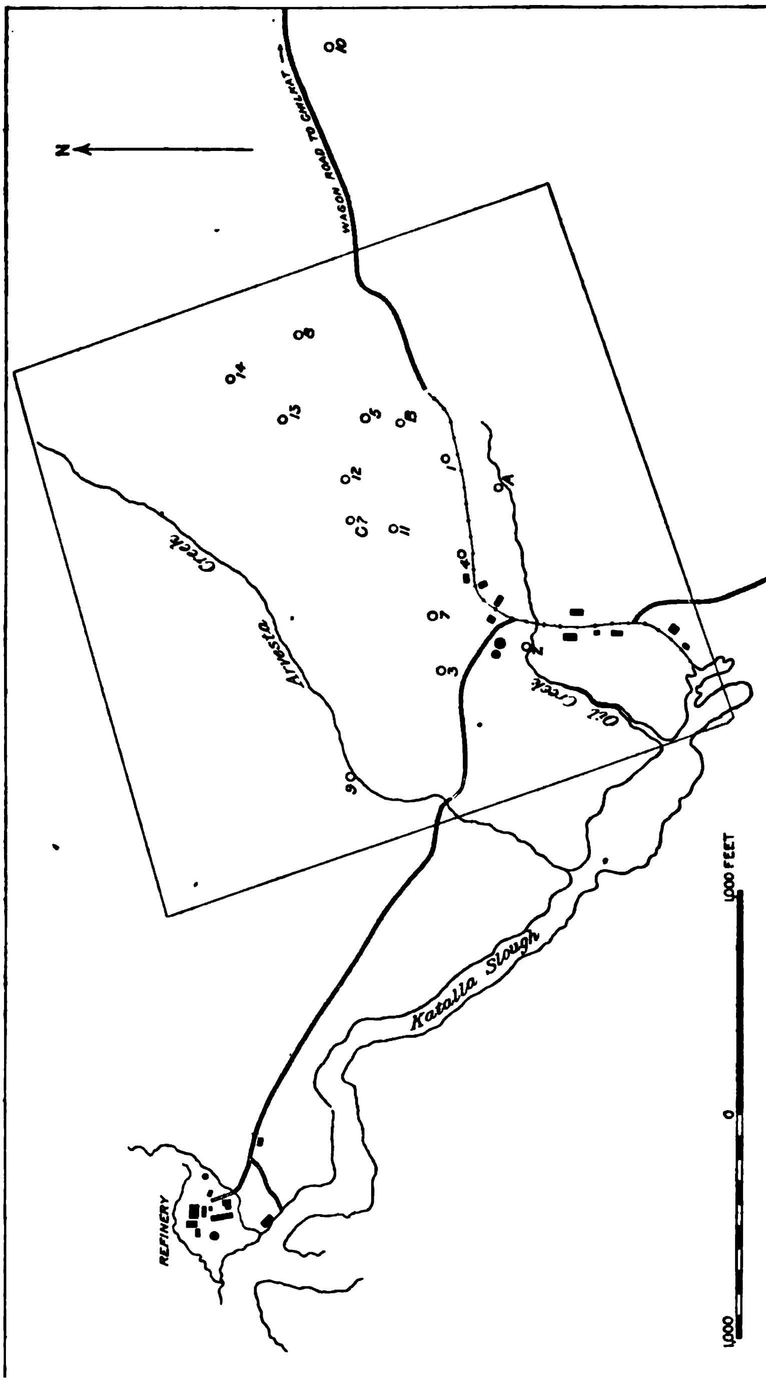


FIGURE 1.—Map showing productive oil wells near Katalla and outline of the patented claim.

results. In 1904 this well was pumped to obtain fuel for use at the other wells of the same company. In 1905 and 1906 the well remained capped, but the oil oozed from around the casing. The well was pumped to get local fuel in 1906 and 1907, and it has been a continuous producer since the refinery was placed in operation in 1912. It yields considerable gas.

The following is a record of this well given by the Alaska Steam Coal & Petroleum Syndicate and reported by F. H. Oliphant:[a]

Record of well No. 1, near head of Katalla Slough.

	Thickness.	Depth.
	Feet.	*Feet*
Surface drift	6	
Decomposed shale	10	16
Light-colored shale	140	156
Fine-grained sandstone, containing 6-inch bed of coal	18½	174½
Dark shale, very hard, including 6 inches of quartz containing iron pyrites	190½	365
Oil sand; flow of oil	1	366
Length of 12-inch casing		220
Length of 9⅝-inch casing		340

According to Mr. Oliphant the drill encounters numerous small showings of petroleum and natural gas and at 366 feet struck a large quantity of oil, which flowed. The well is said to have continued to flow until it was capped.

No. 2. Near head of Katalla Slough. Drilled in 1903 to a depth of about 1,000 feet. Said to have obtained oil at a depth of about 700 feet. Pumped from 1912 to 1919, yielding a small quantity of oil but no gas. Abandoned in 1919.

No. 3. Near head of Katalla Slough. Drilled in 1904 to about 900 feet. In 1905 and 1906 this well remained capped, but the oil squirted at times in strong jets from the casing. The well was pumped for fuel in 1907 and 1908 and has been a constant producer since 1912. It yields a small amount of gas.

No. B. Near head of Katalla Slough. Drilled to an unknown depth in 1904. No oil so far as known.

No. C. In 1903 a derrick was erected on this site and in 1904 a well was probably drilled. No oil was obtained.

No. 4. Drilled in 1912 to a depth of 690 feet, obtaining oil between 400 and 500 feet. The well has been pumped since 1912, yielding both oil and gas.

No. 5. Drilled in 1912 to a depth of about 1,000 feet. A small quantity of oil was obtained at 650 feet and the main flow at 800 feet. This well is one of the larger producers of oil on the patented claim and it also yields some gas.

No. 6. Drilled in 1912 to a depth of 100 or 200 feet and abandoned without obtaining oil because of the loss of the rotary bit.

No. 7. Drilled in 1912 to a depth of 645 feet. Small showings of oil were obtained from 300 to 450 feet and the main flow was struck at 450 feet. Yields both oil and gas.

No. 8. Drilled in 1913 to a depth of about 1,100 feet. A small quantity of oil was obtained between 700 and 800 feet. The well was pumped in January, 1917, but not since then. It yielded some gas.

No. 9. Drilled in 1917 to a depth of 1,810 feet. Some oil was obtained at 650 and 1,000 feet, but not enough for pumping. The well yields a small quantity of gas from a depth of 350 feet.

[a] The production of petroleum in 1902: U. S. Geol. Survey Mineral Resources, p. 583, 1903.

No. 11. Started June 6, 1918, and finished July 9, 1918. Drilled to a depth of 1,130 feet, entirely in shale. Produces about 3 barrels a day. The well is on claim No. 1 and is about 350 feet from well No. 4 and in line between well No. 4 and the northeast corner of the claim. Oil was obtained at 490 feet and from 590 to 1,000 feet, and gas at 380 and 475 feet.

No. 12. Started July 27 and finished September 7, 1918. Drilled to a depth of 903 feet, entirely through shale. This well produced about 8 barrels a day. It is about 350 feet northeast of well No. 11, on claim No. 1. It struck a slight showing of oil at 330 feet, a slight increase at 480 feet, and a big increase at 590 feet.

No. 13. Started in September, 1918, and finished in June, 1919. Drilled to a depth of 900 feet, entirely through shale. Produces about 20 barrels a day. This well is 350 feet northeast of well No. 12, on claim No. 1. The first oil obtained in this well was struck at 635 feet and a strong flow at 770 feet. Gas was obtained at 637 feet.

No. 14. Started in July, 1919, and drilled to a depth of 1,410 feet. Drilling discontinued November 1, 1919, for the winter. This well is about 350 feet northeast of well No. 13, on claim No. 1, and is drilled entirely through shale. A little gas and a showing of oil were found in this well, but no "pay." This well was drilled to 2,265 feet in 1920, but no oil was obtained.

No. 15. Derrick erected in 1920 and drilling was probably started in the fall.

No. 16. Drilled in 1920 to a depth of 740 feet. Some oil is produced. Oil was obtained at 365 feet, 510 feet, and 740 feet. The greatest yield was at 740 feet.

No. 101. The so-called Rathbun well, on the west shore of Bering Lake, was drilled in 1905 and 1906 to a reported depth of about 1,700 feet. Drilling was frequently interrupted by accidents to the machinery. It is not known that any oil was obtained.

No. 102. East shore of Bering River. Begun in 1903. Abandoned without reaching bedrock at a depth of 580 feet because of difficulty in sinking casing through the mud.

No. 103. Chilkat Creek on Chilkat No. 10 claim. Drilled in 1904 to a depth of about 400 feet, and said to have been abandoned because of the loss of tools. No oil, gas, or water is to be seen in the casing, and it is said that no oil or gas was obtained.

No. 104. Edge of tidal flats 1 mile west of mouth of Bering River on Chilkat No. 11 claim. Drilled in 1904 to a depth of 600 or 700 feet. It is said that the well was abandoned because the tools were lost in it. Water now stands near the top of the casing. Gas bubbles through the water almost continuously, and it is said that globules of oil occasionally rise to the surface.

No. 105. Edge of tidal flats a short distance northwest of No. 104 on Chilkat No. 11 claim. Drilled in 1904 to a depth of about 800 feet. Oil now stands near the top of the casing. Small but continuous flow of gas. The amount of oil has not been estimated. The well has never been pumped, but it is reported that oil has been bailed from it for local use.

No. 106. Clarence Cunningham's well No. 1, on Strawberry Harbor. The derrick was built on piling about 1,000 feet offshore. Casing sunk deep into the mud in 1904 without reaching bedrock.

No. 107. Clarence Cunningham's well No. 2, on Strawberry Harbor. Drilled several hundred feet in 1904 without obtaining oil.

No. 108. Tributary of Redwood Creek on Redwood No. 11 claim. Drilled to a depth of about 1,000 feet in 1904. Oil now stands a few feet below the top of the casing. The quantity of oil is not known, as the well has never been pumped.

No. 109. This is well No. 10 of the Chilkat Oil Co. and is on Redwood No. 12 claim. Drilled in 1917 to a depth of 1,613 feet. Small quantities of oil were found at depths of 1,050, 1,230, and 1,613 feet, and of gas at 260, 290, 460, and 1,520 feet. The well was abandoned because of caving.

No. 110. Alaska Petroleum & Coal Co.'s well No. 1, between the head of Katalla Slough and Cave Point. Drilled in 1903 to 1,710 feet and abandoned because limit of outfit was reached. No flow of oil was found, but it is said that a little oil was brought up in the bailer from time to time.

No. 111. Alaska Petroleum & Coal Co.'s well No. 2, on Katalla River. Casing sunk to a depth of 280 feet in 1903 without reaching bedrock.

No. 112. Alaska Petroleum & Coal Co.'s well No. 3, near Katalla. Drilled in 1904 to a depth of about 1,500 feet.

No. 113. Alaska Petroleum & Coal Co.'s well No. 4, near Katalla. This well, which is very near the site of well No. 3, was drilled in 1905 and 1906 to a depth probably exceeding 1,500 feet.

No. 114. Alaska Petroleum & Coal Co.'s well No. 5, on the west line of Bangor No. 3 claim and the east line of Tuttle No. 3 claim, was drilled to a reported depth of 1,600 feet in 1907. It is said that no oil was found.

No. 115. Alaska Coal Oil Co.'s well No. 1, on the south line of the Alhambra No. 2 and the north line of the Crescent No. 2 claim on Mirror Slough. This well was begun in 1911 and had been drilled in 1917 to a depth of 1,040 feet. Oil and gas were encountered at 700 feet. In 1917 an attempt was being made to bail out and shut off the water. A small quantity of oil was brought up in the bailer and there was a strong flow of gas whenever the pressure of the water was reduced.

SEEPAGES.

OCCURRENCE.

Petroleum seepages and gas springs are numerous in many parts of the oil belt, and the flow of oil or gas at some of them is large. The seepages all occur (see Pl. IV) within a long, narrow belt extending from the edge of the Copper River Delta eastward to Bering Glacier, a distance of about 28 miles. This belt is very narrow, not more than 4 miles wide at any known point, and is in general parallel to the coast. The seepages at Yakataga (see pp. 37–38) are in a belt having the same general direction and lying practically in line with it. Several of the smaller groups of seepages, such as the group on Redwood Creek and at the head of Katalla Slough, and the groups on Burls Creek, on Chilkat Creek, and in the Nichawak region, have a distinct linear arrangement, each running about N. 15° E. These lines coincide with the directions of the valleys.

Several large oil seepages were seen by the writer on the banks of Mirror Slough near the mouth of Martin River. At some of these the petroleum reaches the surface through the clay and mud of the valley floor, and a large quantity has accumulated in the pools on the swampy surface and in the soil. The nearest outcrops of hard rocks are sandstones or graywackes, probably of Tertiary age and possibly belonging to the Katalla formation. At two localities, one near the

derrick on Crescent No. 2 claim and one near Sinclair's cabin, about a mile east of the derrick, the seepages have been excavated and small but continuous flows of oil obtained from bedrock.

Seepages were also seen near the head of Mirror Slough, at the base of Ragged Mountain. The oil here reaches the surface through soil that is immediately underlain by either glacial drift or by talus or landslide débris. The underlying rock is probably slate or graywacke. Another seepage about a mile south of this point, in a canyon just north of Bald Mountain, was visited by the writer. The oil was here seen oozing in small quantities directly from the joints and bedding planes of the steeply dipping slate, chert, and graywacke.

Oil is reported to have been seen in large quantities on the surface of the water of the small ponds and the creek at the south end of the town of Katalla after the earthquake of 1899. The surface material consists largely of rock débris derived from Ragged Mountain, and is underlain by the soft shales of the Katalla formation.

Numerous and copious seepages are to be seen in the vicinity of the wells at the head of Katalla Slough. (See Pl. V, *A*.) The oil impregnates the soil at many points and has accumulated in large quantities on the surface. These accumulations are chiefly oil, not residues, such as those at the California brea deposits.

On the west slope of the valley of Redwood Creek, about 1½ miles northwest of the mouth of the creek, near a well (No. 108, Pl. IV), oil can be seen coming directly from soft, fissile, iron-stained shale. The shale has been broken into small angular fragments and recemented by ferruginous material. This recemented rock is common at or near seepages in these shales and is believed to be a fault breccia. Here, as at many other seepages, sulphur springs are associated with the oil. Another seepage was seen near the headwaters of Redwood Creek, where oil flows directly from the shale.

It is reported that oil may be seen at low tide in the beach sands on the north shore of Strawberry Harbor. The rocks in the vicinity are sandstone and shale, which probably belong much higher in the stratigraphic column than the soft shale found at the seepages already described.

Several seepages occur along the wagon road that leads from the head of Katalla Slough to the mouth of Bering River. Two of these are about a mile and a half west of Burls Creek, close to the road. The quantity of oil at one of these seepages is large. The nearest visible rock is steeply dipping conglomerate, which crops out a few feet away, but the oil can be seen only on the surface of the soil, its direct source not being visible. At the other seepage in this locality a tunnel that has been driven into the hillside reveals a small but continuous flow of oil from bedrock.

OIL SEEPAGE NEAR HEAD OF KATALLA SLOUGH.

On Barrett Creek above the wagon road, near the locality last mentioned, oil flows continuously from the bedding planes and joints of the rocks exposed in the bank of the creek.

In the upper part of the valley of Burls Creek there are many seepages at which the oil oozes directly from steeply dipping shales that here contain a large quantity of glauconite, which gives the rock a bright-green color. Thin sections show abundant casts of foraminifers and diatoms. Large calcareous concretions are abundant, and some of them have the form of septaria filled with calcite. Organic remains consisting chiefly of mollusks and crabs are seen in many of these concretions. The soft shale also is rich in organic material, some beds being so dark as to resemble impure coal. The writer saw no coal in these rocks, however, either at this locality or elsewhere. The rocks at this point seem to be very strongly impregnated with oil, and seepages are numerous, but large surface accumulations are rare. Broken shale recemented by ferruginous material was seen here, as on Redwood Creek.

Some seepages at which considerable oil has accumulated were seen along the edge of the tidal flat, close to the wagon road, halfway between Burls Creek and the mouth of Bering River. No outcrops were seen near these seepages, but fragments of shale indicate the presence of beds of that rock.

Several seepages have been reported from Chilkat Creek. The largest one seen by the writer is in the west bank of the creek 1½ miles above the forks of the wagon road. The oil reaches the surface through soft, brecciated shale whose beds have a steep westerly dip. The seepage is associated with a black sulphur spring.

Many seepages have been reported in the group of hills centering around Nichawak Mountain. Those seen by the writer were small, but the oil issued directly from the rock, which is shale resembling that at the seepages west of Bering River. Others are reported to occur on the banks of a small lake, the surface of which is said to be covered at times with oil. The most conspicuous seepages are on Kathleen, Yuclaw, and Yakogelty creeks. (See analysis, pp. 31–32.)

Seepages have been reported from many parts of the Controller Bay region, but some of them, especially those seen in the mud on the tidal flats, are believed to be only decaying organic material or films of iron oxide. Many of the sulphur springs may bear no relation to any accumulations of petroleum.

Inflammable gas comes to the surface of the water in large quantities at several places. The largest of the "gas springs" seen by the writer are in Mirror Slough and in Katalla River. The gas from the spring in Mirror Slough will furnish a large, continuous flame. It issues from the mud on the bottom of the slough. Its

composition is not known. It may be ordinary swamp gas derived from the decay of organic material in the mud, but it is more probably a true natural gas derived from bedrock, for it issues forth in large quantity at a point close to oil seepages. Most of the productive oil wells and several of the nonproductive wells yield considerable natural gas. (See p. 15.)

SIGNIFICANCE.

A petroleum seepage or oil spring is a place at which there is natural escape of petroleum to the surface, either directly from the outcrop of the oil sand or through some joint or fault plane or crushed and porous zone that extends from the oil sand to the surface. As soon as the oil reaches the surface it either dries up or flows away. In the cool, moist climate of the Katalla district there is comparatively little opportunity for residues to accumulate. The oil is washed away rapidly, so that at most of the seepages no residues are seen, and the oil becomes completely dissipated a short distance from its point of escape. The presence of residues in this region therefore means either that large quantities of oil are escaping or that exceptional conditions prevent the oil from being washed away, or more probably both. At some places, as at the well-known seepages at the head of Katalla Slough, large quantities of absorbent material, such as peat, may have permitted the accumulation of residues. As the oil at the surface is rapidly washed away in this region the presence of fresh oil in the soil or on standing or running water generally indicates that its immediate source is close at hand. At most of the observed seepages either close inspection of the natural exposure or a small amount of excavation has revealed the oil issuing from bedrock. At no seepage, even where the quantity of oil was large, did the writer see the oil traveling very far, for it is soon so completely washed away as to be unobservable. It may be safely concluded that any large quantity of fresh oil in the soil or on standing or running water in this district has its immediate source within a few feet, if not within a few inches, horizontally, of the place where it is observed. Most of the immediate bedrock sources will probably be found within a short vertical distance of the point where the oil comes to the surface. The presence of a residue in this region indicates that oil is escaping in large quantity and that its immediate source is directly beneath the highest point on the surface of the residue. The ultimate source of the oil within the bedrock, however, can be determined less definitely.

The seepages at the head of Katalla Slough and on Redwood, Burls, and Chilkat creeks are all in the soft shales that compose the middle part of the Katalla formation. Those between Redwood and Burls

creeks are associated with conglomerates of presumably higher position. The seepages in the Nichawak region that were seen by the writer are in shales which closely resemble the soft shales just referred to. The seepages on Mirror Slough and at the neighboring localities west of Katalla are in an area of highly folded sandstone or graywacke that may be the equivalent of part of the Katalla formation.

The position of the seepages with reference to the structural features is somewhat uncertain. The seepages west of Katalla are on steeply folded and slightly metamorphosed beds whose detailed structural features have not been determined. The group of seepages on Redwood Creek and Katalla Slough is apparently close to a fault.

The seepage on Burls and Redwood creeks are possibly near the axes of anticlines. The Redwood Creek anticline, if it exists, is probably broken near or west of its axis by a fault. The seepages between Burls and Redwood creeks are on monoclinal beds of conglomerate. The general structure in the Nichawak region has not been determined, but the beds near the seepages have a steep dip and are probably closely and complexly folded.

It seems, therefore, that, although small groups of seepages lie along local structural lines, the general occurrence of all the seepages in a long, narrow belt, running east and west, diagonal to the structure and to the belts of outcrop of the various kinds of rock, is unexplained. The existence and position of this belt of seepages must, however, be related to the stratigraphy and structure of either the surface rocks or of some rocks that do not crop out. Among the systems that are represented at other localities on the Pacific coast of Alaska but that have not been recognized in this district is the Jurassic, rocks of which on the west shore of Cook Inlet and on the Alaska Peninsula have yielded oil (see pp. 53, 66) that is of the same kind as that of Controller Bay and very different from most of the Tertiary oil of California and other oil fields on the Pacific coast. The inference naturally follows that the petroleum of Controller Bay might be derived from Mesozoic rocks that lie beneath Tertiary rocks.

To account for the occurrence of the oil, however, it is not sufficient to suppose merely that it is derived from buried Mesozoic oil-bearing rocks, for if these have the same structure as the Tertiary rocks at the surface the chief difficulties will still remain. Nor will it be sufficient to assume that the Mesozoic rocks underlie the Tertiary rocks unconformably, for then the Mesozoic rocks would have a structure at least as complex as that of the Tertiary rocks. If, however, there was, in late Tertiary or in post-Tertiary time, a zone of intense deformation that lay in the present geographic position of the Chugach

Mountains but did not extend into the coastal part of the region here described; if the Tertiary rocks that now crop out on the shore of Controller Bay then lay well to the north of their present position and were involved in this deformation; and if, in the final stage of the deformation, the Tertiary rocks rode southward in one or more great overthrusts and came to rest upon Mesozoic strata that were at a distance from the zone of intense deformation and were therefore not deformed, we should then have in the present Controller Bay region complexly folded rocks at the surface resting upon buried rocks of simpler structure and perhaps not folded at all. If these possible conditions really existed a fault parallel to the coast and to the mountains would account for the position and character of the shore and would permit oil to come up from its original source in the possibly nonfolded buried Mesozoic rocks to its present apparent source in the complexly folded Tertiary rocks at the surface. The structure of the underlying rocks and the position of the fault or faults would thus determine the position of the major east-west belt of seepage, and the structure of the more intricately folded rocks at the surface would determine the positions and the details of the minor northeast-southwest groups of seepages.

The possibility tentatively suggested above removes the difficulty of accounting for light-gravity oils in complexly folded and faulted rocks and explains the occurrence of the seepages in a narrow zone diagonal to the trend of the folds, parallel to the mountains along the general east-west shore line, and in line with the belt of seepages at Yakataga. This possibility should be borne in mind in further local geologic studies or in interpreting the position of apparent oil sands in wells or at seepages. It should be noted, however, that there is no reason to believe that any such possible Mesozoic oil-bearing strata are within reach of the drill. If present at all, they probably lie at great depths.

CHARACTER OF THE PETROLEUM.

The following statement concerning the character of the oil now being obtained from the productive wells has been furnished by Dr. A. M. Bateman:

> The gravity of the oil is from 41½° to 45° Baumé. The oil is high in gasoline and naphtha and has a paraffin base. Sulphur is absent. The recoverable content of gasoline and distillate is about 68 per cent.

The following analyses and tests of samples of oil from wells and seepages in the Katalla field have been published. The samples of seepage oil probably have not the same properties nor do they yield so large a proportion of the more volatile constituents as the "live" oil in the wells.

Test of petroleum from well No. 1, Katalla Slough.[a]

	Per cent.	Gravity at 15° C.	
		Specific.	° Baumé.
Distillation by Engler's method:			
Benzine (80°–150° C.)	21	0.7573	54.9
Burning oil (150°–300° C.)	51	.8204	40.6
Residuum (paraffin base)	28	.9096	23.9
Sulphur	Trace.		
Gravity of crude oil		.828	39.1

[a] Sample collected by G. C. Martin from well No. 1 in 1903. Analysis and statement of properties by Penniman & Browne, of Baltimore. Published in U. S. Geol. Survey Bull. 250, p. 57, 1905.

The burning oil was purified by concentrated sulphuric acid and soda, the volume of acid used up being too small to measure. The purified burning oil was put into a small lamp, where it burned dry without incrusting the wick or corroding the burner, and without any marked diminution of flame. The burning oil compares very favorably in these respects with Pennsylvania oil prepared in the same way.

Test of petroleum from well No. 1, Katalla Slough.[19]

Specific gravity at 60° F., 0.7958=45.9° Baumé.
Cold test: Did not chill at 3° F. below zero.
Distillation:

Below 150° C., naphtha	38.5
150° to 285° C., illuminating petroleum	31
Above 285° C., lubricating petroleum	21.5
Residue, coke, and loss	9

Physical properties of crude petroleums.[a]

Locality.	Specific gravity.	Flashing point (Abel test).	Color.
		°F.	
Burls Creek	0.942	234	Dark reddish brown.
Katalla Meadow, 1	.929	240	Dark brown.
Katalla Meadow, 2	.901	156	
Katalla Meadow, 3	.874	156	
Katalla Meadow, 4	.869	152	
Katalla Meadow, 5	.961	266	
Bore hole at Katalla, 120 feet (1902)	.802	Below 60	Dark red.
Bore hole at Katalla, 355 feet (1902)	.790	Below 60	Do.
Yakogelty Creek	.937	246	Dark brown.

[a] Redwood, Boverton, Petroleum, 3d ed., vol. 1, p. 205, 1913.

Commercial products of crude Alaska petroleum.[a]

Specific gravity.	Petroleum spirit (benzine).	Kerosene.	Intermediate and lubricating oils with solid hydrocarbons.	Coke.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
0.869		19.0	78.6	1.7
.914		9.0	87.6	2.7
.800	24.8	53.9	16.7	1.2

[a] Redwood, Boverton, op. cit., p. 228.

[19] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1902, p. [illegible], 1903.

The analyses given below were published by Stoess.[11]

The following analysis was made in Seattle from a sample of the crude oil taken from the well at Katalla:

Analysis of oil from Katalla well.

Specific gravity, 0.800.

Naphtha	34.2
Illuminating oil	34.4
Lubricating oils	16.5
Coke and residue	14.5

Another analysis [possibly the same as that published by Oliphant and quoted above], made in Los Angeles, Cal., gave:

[*Analysis of oil from a point near Katalla.*]

Specific gravity, 0.7957 (45.9° B.).

Cold test, not chilled at 3° below zero.

Naphtha	38.5
Illuminating oil	31.0
Lubricating oil	31.5
Coke and loss	9.0

Oil has a flash test of 70° to 80°. Oil is light green in color.

The results of the foregoing analyses and tests on oils from the Controller Bay region are brought together in the following table:

Summary of analyses and tests of petroleum of Controller Bay region.

Locality.	Color.	Gravity.		Flashing point.	Benzine.	Kerosene.	Lubricating oil.	Residue, coke, and loss.
		Specific.	Baumé (°).					
				°F.	P. ct.	P. ct.	P. ct.	P. ct.
Katalla Slough, well No. 1.		0.8280	39.1		21.0	51.0	28.0	
Do		.7958	45.9		38.5	31.0	21.5	9.0
Do	Light green	.7957	45.9	70-80	38.5	31.0	21.5	9.0
Do		.800			34.2	34.4	16.5	14.5
Do	Dark red	.802		(a)				
Do	do	.790		(a)				
Unknown		.869				19.0	78.6	1.7
Do		.914				9.0	87.6	2.7
Do		.800			24.8	53.9	16.7	1.2
Burls Creek	Dark reddish brown	.942		234				
Katalla Meadow	Dark brown	.929		240				
Do		.901		156				
Do		.874		156				
Do		.869		152				
Do		.961		266				
Yakogelty Creek	Dark brown	.937		246				

a Below 60° F.

CONCLUSIONS.

Prospecting and drilling in the Controller Bay region will be expensive, owing to the geographic conditions, but these conditions may be permanently improved without great engineering difficulties or excessive cost.

[11] Stoess, P. C., The Kayak coal and oil fields of Alaska: Min. and Sci. Press, vol. 87, p. 65, 1903.

The geology is complex and difficult to interpret and does not show definitely the relation of the occurrence of the petroleum to the stratigraphy and structure. The local geology, so far as known, is not especially favorable to the occurrence of productive bodies of oil and indicates that if oil is found in quantity the productive areas will be very irregular in distribution and difficult to locate. However, if future developments confirm the theory that an overthrust along the coast (pp. 29-30) separates the complexly folded rocks at the surface from rocks of simpler structure below, the conditions may be much more regular and more favorable to the development of a good oil field than the surface conditions indicate.

The surface oil showings (seepages), though widespread and copious, do not furnish conclusive evidence of the occurrence of large bodies of oil but apparently give more promise than any of the other known geologic features of the region. The only safe conclusion they warrant is that the rocks near them contain some oil.

The net result of the drilling has been to show the existence of moderate quantities of oil in at least a part of the region, notably within the area of the patented claim, where most of the successful wells have been drilled. The wells outside the area of the patented claim are neither numerous enough nor deep enough to determine the outline of the pools and the area of productive territory or to show whether oil exists in sufficient quantity to pay for exploitation. They have demonstrated the difficulty and expense of drilling and the need of ample resources and careful management. The existence of oil in remunerative quantities in the greater part of the district has neither been proved nor disproved. The evidence afforded by the existing wells, like that afforded by the seepages, is sufficient to warrant further testing, if the tests are made intelligently and carefully by companies strong enough to exploit large areas on a scale that permits wholesale economies, and also strong enough to risk their capital on what must certainly be regarded as a speculation rather than an investment.

Operators and investors who may not be familiar with local conditions will do well to be governed by the following suggestions:

1. They should be certain that legal title can be obtained to a sufficient area to make it possible to sink many test wells under widely differing conditions and to permit a large enough probable production to pay for heavy initial expenditures and large permanent improvements.

2. They should have enough capital to be able (*a*) to purchase in quantity and at low rates; (*b*) to build good roads and other improvements and thus reduce cost of operating; (*c*) to carry a large stock of tools and supplies, in order to avoid costly delays in drilling

and to be able to drill deep; (*d*) to procure the best professional advice and good drillers; (*e*) to drill many test wells without hope of immediate profit; and (*f*) to afford to lose the investment.

3. The first wells should be located on the strike and at no great distance from producing wells, or down the dip from a good seepage and at such varying distances that the rocks outcropping at the seepage will be encountered at depths ranging from a few hundred feet to the limit (in depth) of drilling.

4. Subsequent wells should be determined in position by the location of existing wells and by the structure. With respect to productive wells, they should be along the strike and close to the wells; with respect to nonproductive wells they should be either not along the strike and at a short distance, or along the strike and at a considerable distance from the wells.

5. Drillers and tool dressers should be obtained from regions where there is difficulty in keeping the holes straight.

6. If oil is obtained, it will probably be down the dip, rather than up the dip from a seepage; in shallow wells near a seepage, in deeper wells farther from a seepage.

YAKATAGA OIL FIELD.

INTRODUCTION.

The Yakataga oil field is on the Pacific coast of Alaska about midway between Controller and Yakutat bays. Oil seepages were discovered at Yakataga in 1896 and oil claims have been staked and surveyed, but no wells have been drilled. The earlier accounts [12] of the geology and petroleum were based chiefly on observations made by F. H. Shepherd and J. L. McPherson, who in making surveys for some of the oil claimants also took notes on the geology, which they did not publish themselves but generously turned over to members of the Geological Survey.

A geologic and topographic reconnaissance survey of this region was made in 1913 by A. G. Maddren, who prepared a brief report [13]

[12] Eldridge, G. H., The coast from Lynn Canal to Prince William Sound in maps and descriptions of routes of exploration in Alaska in 1898 (U. S. Geol. Survey Special Pub., p. 104, 1899.

Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 264, 1900.

Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 26–27, 1905.

Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 26, 63, 114, 115, and 118, 1908.

[13] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 119–153, 1914.

on it that was published by the United States Geological Survey. Maddren's report is the basis of the description given below.

GEOLOGY.

The rocks of the Yakataga oil field include shales, sandstones, and conglomerates having an aggregate thickness of possibly 7,000 or 8,000 feet. Sandstones form the most massive and shales the thickest and most persistent beds in the section. The only limestones known are thin bands in some of the thicker beds of shale, several of which are somewhat calcareous throughout several hundred feet of strata, but even these contain numerous sandy and gravelly layers. In general, calcareous and sandy shales are more abundant in the lower part of the section, but conglomerates and sandstones also occur there. Thick beds of shale lie near the top of the section and thinner layers of shale are interbedded with many of the conglomerates. Some of the pebble beds have a shale matrix containing marine shells. These rocks are thrown into a series of folds, in part open, in part closely compressed, whose axes trend about N. 70° W. There are some faults. No igneous rocks have been found.

The oldest of these strata consist of calcareous shales and thin limestones with some interbedded sandstones and a few thin beds of conglomerate. They are exposed in a belt that runs along the anticlinal axis and the line of seepages which extends eastward parallel to the coast from a point near Yakataga Reef to Johnston Creek.

These beds are succeeded above by a great series of sandstones and shales and some beds of conglomerate, which together make up the lower part of the ridge separating the valley of White River from the coastal plain and also occur west of the valley of White River and near Icy Bay. Similar rocks are found in the second ridge from the coast, between White and Yakataga rivers.

About 1,000 to 1,500 feet of buff sandstone occurs in the upper part of the ridge that lies between the coast and White River, and similar rocks occur in the two ridges to the west.

This sandstone is succeeded by a great series, more than 2,000 feet thick, of buff sandstones and shales and some beds of conglomerate. These rocks form the ridge between White and Yakataga rivers and also occur in the next ridge to the north, where they are overlain by presumably older coal-bearing rocks brought up by a great fault. The highest known rocks of this section include massively bedded marine shale and sandstone, 2,000 to 4,000 feet thick, containing a great number of large and moderate-sized boulders of various kinds of crystalline rocks, which have apparently been dropped by icebergs. These boulders are scattered through several thousand feet

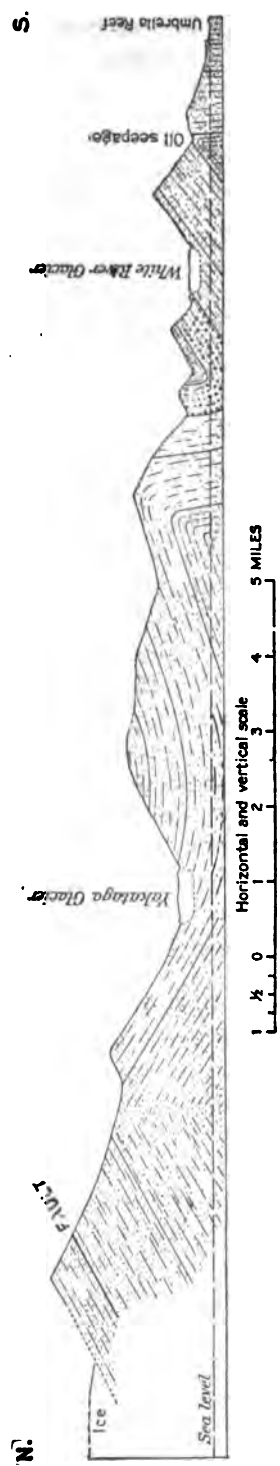


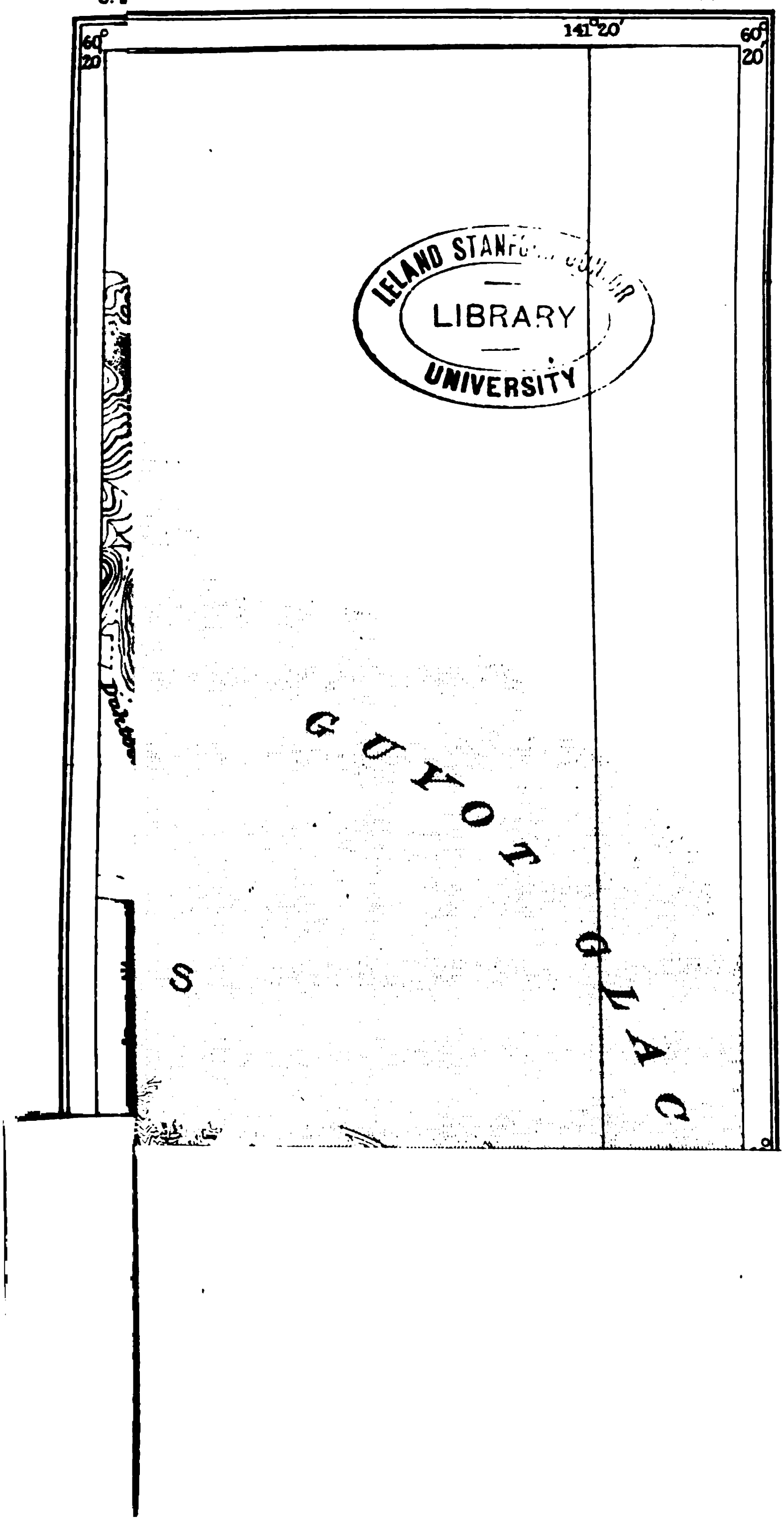
FIGURE 2.—Sketch showing structure in Yakataga field.

of silty sandstones and shales. This f mation occurs at Umbrella Reef on t coast and in the ridge west of White Riv

The precise ages of the strata describ above have not been definitely determin Many of the beds carry invertebrate fo sils, but most of these are so much crush as to be difficult to identify. Moreover, t conditions under which Maddren did h field work did not permit him to make a carry large collections. Maddren[14] h tentatively assigned the several strata various horizons ranging from Oligoce to Pleistocene and has quoted lists of fossi determined by W. H. Dall, in which th known stratigraphic occurrence of eac recognized species in other regions is citec The writer believes that the evidence indi cates that the sandstones and shales whicl make up the greater part of the section ar probably all Miocene, and that the highes conglomerate is possibly Pliocene.

The Robinson Mountains, where studied, consist of a series of folds whose axes trend about N. 70° W. A closely compressed anticline is marked by the minor valleys along which the petroleum seepages are found. This anticline pitches west, and its nose is at Yakataga Reef. Its northern limb includes the rocks west of the valley of White River, beyond which there is a syncline. The anticlinal fold is marked by the broad ridge south of the valley of Yakataga River, and the valley itself occupies a synclinal trough. The next highland mass to the north is anticlinal. A great fault lies along the west limb of this anticline, by which the supposed Eocene coal-bearing rocks are thrust over other sediments, probably Pliocene. These structural features are believed to dominate the area, though it may contain other unrecognized faults. (See fig. 2.)

[14] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 127, 130–131, 1914.


141°20'
60° 20'
60° 20'
GUYOT GLAC
S

PETROLEUM.[13]

All the best-known petroleum seepages of the Yakataga district are near the base of the seaward slopes of the coastal ridge of Robinson Mountains. (See Pl. VI.) These seepages are distributed along a line extending from a point near Yakataga Reef to Johnston Creek, a distance of about 18 miles. They are from half a mile to 2 miles from the beach. About a dozen seepages are distributed at irregular intervals along this line, but the easternmost, on Johnston Creek about 1½ miles above its mouth, is the only one of considerable volume. Most of these seepages are little more than meager indications of oil in the form of sulphurous coatings or exudations along joint cracks of the rocks, or iridescent films over moist rock surfaces and on any small pools of water that may be collected near by. Thick oily residue has accumulated in notable quantity only at the seepage on Johnston Creek. Here the discharge of rather fresh petroleum is free enough to furnish considerable quantities to the swift-flowing, turbulent stream, so that appreciable quantities of oil are carried down its course to the ocean. A scum of oily residue also occurs on the cobble bars of Johnston Creek from its mouth up to the seepage. Probably a barrel or more of petroleum a day escapes from this seepage. The odor of petroleum was also noted at the mouths of Munday, Poul, Lawrence, and Crooked creeks, small streams that flow across the narrow coastal plain west of Johnston Creek. (See Pl. VI.) The seepages on these streams are from 1 to 2 miles above their mouths and are not so indicative of the free escape of oil as the one on Johnston Creek.

Prospectors report the occurrence of petroleum seepages in the second ridge of the Robinson Mountains from the coast. Prospectors also report a strong petroleum seepage east of Icy Bay and not far from Yahtsee River. This locality may mark an eastern extension of the Yakataga oil field.

The westernmost of the main line of seepages lies near the base of the mountain slope, where it joins the coastal plain, whereas those to the east lie in valleys separated by minor ridges from the seaboard. This line of seepages in part marks a series of depressions, extending east and west, occupied by the headwaters of streams flowing southward. The chain of depressions between the foothill belt and the main mountain front appears to lie along the axis of a symmetrical anticline, whose south limb is sharply flexed into a nearly vertical position and the dip of whose north limb is 15° to 45° N. All the seepages of petroleum reach the surface along the axial zone of this anticlinal flexure, which strikes about N. 70° W. The rocks, which are sandstones and shales, are provisionally assigned to the Oligocene.

[13] The discussion under this heading is reprinted from Maddren's report essentially without change.

The development of the depressions between the foothill belt of vertical strata and the main mountain front at right angles to the north and south trunk gorge valleys across that belt is primarily caused by the more rapid erosion and removal of material that has occurred along the zone of the anticlinal axis. Here the sharp flexuring of the strata has shattered the rocks, and thus exposed them to the more rapid disintegration and consequent removal by the streams.

The strata at the base of the exposed portion of the section in the vicinity of Johnston Creek seepage are chiefly made up of sandstones that are favorable for either storage or migration of petroleum. These sandstones are overlain by close-textured shales, which may have served as the retentive cover. The liberal escape of fresh oil at this locality might be used as an argument for considering this horizon—the lowest rocks exposed in the coastal mountain ridge—to be at or near the ultimate oil-bearing horizon. This can not, however, be demonstrated without drilling, and there are some strong arguments against this hypothesis which will not here be presented.

Several seepages occur at or near the base of the seaward slopes of the coastal mountain west of the lower White River valley and extend nearly to Yakataga Reef. Here all the outcropping strata belong to the moderately northward-dipping limb of the anticlinal fold, the south limb being covered by the coastal-plain deposits or the ocean. The geologic structure of Yakataga Reef indicates distinctly the plunging nose of the anticline marked by the seepage.

The crest of this anticline appears to have a decided inclination to the west, but the dip is not so marked as that of its terminal nose at Yakataga Reef. This westward inclination amounts to a fall of at least 2,000 or 3,000 feet in the distance of about 18 miles along the seepage belt.

As the ultimate source of the petroleum at Johnston Creek seepage may be near if not at the outcrop from which the free flow of fresh oil comes (about 100 feet above sea level), it may be supposed that the oil-bearing bed becomes progressively deeper westward along the anticlinal axis. If this is so, it must be heavily covered by a greater thickness of strata in this direction. This may account for the more scanty escape of oil at the seepages in the western part of the belt. These views are based on the assumption that there is only one oil-bearing stratum developed along the anticline—the one marked by the free-flowing Johnston Creek seepage. All this is mere assumption, for there may be oil-bearing beds at several horizons in the section. There are in the exposed section several extensively developed porous sandstone and conglomerate members with impervious capping of fine-textured shale that should afford storage ' troleum. Some of these, where under deep cover toward the

western part of the anticline, may contain oil. Only intelligently directed drilling will determine these matters.

The evidence in hand indicates that the search for oil here should not be nearly so involved with structural complexities as in the Katalla oil field, in the Controller Bay district. In the Katalla field folding and faulting are so intricate that the drilling thus far done has not proved very satisfactory. The essential structural features in the Yakataga seepage belt do not seem to be any more complex than those in some of the productive fields of California. If anything, the structure governing the occurrence of petroleum in the Yakataga district is probably more simple than that of some of the well-known California fields. If this is true, possibly only a small amount of intelligent drilling will be necessary to test the commercial value of the Yakataga belt. The inaccessibility of the field and the local difficulties of transportation will be strong deterrents to development. The discussion of transportation is reserved for a later section of this report.

There are no complete tests of the petroleum from the Yakataga district, and, in the absence of any drilling, such as have been made are necessarily tests of samples taken from seepages in which there has been a loss of the volatile compounds. There is every reason to believe that the Yakataga petroleum is of the same high grade as that of the Katalla field. The Katalla petroleum is a refining oil of the same general nature as the Pennsylvania petroleum. Like that oil, it has a high percentage of volatile compounds, a paraffin base, and almost no sulphur. The following table summarizes the available information about the composition of the oil from this field:

Summary of analyses and tests of Yakataga petroleum.[a]

Locality.	Color.	Specific gravity.	Flashing point.
Johnston Creek	Dark brown	0.964	200
Do	do	.879	178
Poul Creek	do	.970	250
Do	do	.881	67
Do	do	.914	156
Crooked Creek	do	.921	172
Oil Creek	do	.855	108
Morrison Creek [b]	do	.991	270
Argyll Creek, Icy Bay [b]	do	.962	310

[a] Redwood, Boverton, Petroleum, 2d ed., vol. 1, p. 198, 1906.
[b] The exact localities of seepages where these samples were taken are not known, but they are believed to be in the Yakataga field.

In 1897, soon after the occurrence of petroleum in Yakataga became known, a continuous tract of land about 1¼ miles wide and 20 miles long was located and surveyed along the belt of seepages. This tract included all the known seepages in the coastal ridge of Robinson Mountains and covered the anticlinal axis from Johnston

Creek on the east to its westward-plunging nose at Yakataga Reef. The original locations aggregated some 50 square miles, or about 32,000 acres. Since then, however, the locators have relinquished much of this land in order to concentrate their assessment work on claims covering chiefly the actual seepages.

HARBORS AND TRANSPORTATION.

The Pacific coast between Controller and Yakutat bays, a distance of about 175 miles, is open to the full sweep of the ocean, with no shelter for even a light-draft launch except at Icy Bay. (See p. 41.) The glaciers that bound the district on the east, north, and west make it almost inaccessible by land. There is only one route of approach to it by land, and this presents serious difficulties. It follows the shore for about 50 miles from Cape Suckling, at the east side of Controller Bay, about 30 miles from Katalla. For 30 miles east of Cape Suckling this route passes along the front of Bering Glacier and crosses half a dozen swift glacial streams. All these streams are dangerous because of quicksands. Several are so large that they must be crossed by rafts or boats. The others may be forded at low water, but even under the most favorable conditions fording is hazardous. Two swift glacial rivers that flow between Bering Glacier and Yakataga Reef must be crossed by boats or rafts. All supplies for the journey must be carried, and it is also best to take a canoe. This route is seldom traveled, and only under guidance of those familiar with its dangers. Several men have lost their lives in attempting this trip.

All landings on this part of the coast must be made through the surf in small open boats. The only place for landing with even approximate safety is at Yakataga Reef, a low, rocky point that juts about half a mile into the ocean and affords a slight protection in calm weather, the only time when it is possible to make a safe landing. Southeasterly winds throw breakers against the east side of the reef, southwesterly winds against its west side, and the only time it is not awash is during a low tide when there is no ocean surge.

During the summer of 1903, when beach placer mining was at its height, steamers called at Yakataga Reef, weather permitting, about once a month. Since 1903 steamers have seldom called at Yakataga Reef, for it is not a good roadstead and the sea is rarely favorable for landing. Moreover, the trade is now small. Most supplies are brought from Katalla in launches that are navigated by men who closely observe the weather and who are generally able to foretell the conditions at Yakataga Reef a day or two in advance. At favorable times quick trips are made, generally at night, so that the work of landing the freight may be begun by daylight. This work is usually

done in a few hours, when the launches return to Controller Bay without delay. By this irregular means the district is served with supplies and mail. The weather may be unfavorable for a landing at Yakataga Reef for fully a month.

Until recently Icy Bay was occupied by Guyot Glacier. Since 1904 the ice has retreated and a considerable embayment has been formed, which might be used as a harbor for Yakataga district if it were free from icebergs and if its western shore is deep enough for anchoring lighters near land or for the construction of a pier.

Mr. Maddren's survey of Icy Bay (see accompanying map, Pl. VI) was very hasty and was made without a boat and therefore without soundings. The bay, though its entrance is 7 miles wide, affords considerable shelter. The surf is broken by a bar off Icy Cape, at the southwestern entrance. The drift ice from Guyot Glacier and the shoals on the west side of the bay are adverse to its commercial utilization. The following statement is based on Mr. Maddren's observations in 1913. Later observers report that there is fairly deep water close to the western shore which is clear of ice much of the time and that there is good anchorage off the eastern shore.

The large quantity of drift ice would make it difficult, at least in summer, for boats to land cargoes on the west shore, where they would be available for transportation to the Yakataga district. Cargoes landed on the east side of the bay would not be available because that side is completely surrounded by impassable barriers of glacial ice.

Comparatively small icebergs become stranded on the west side of Icy Bay, which, though not sounded, therefore appears to be rather shallow for at least half a mile from shore, and smaller masses of ice are generally so closely packed along this shore for a width of a quarter of a mile that even small boats would find it difficult to land. It is questionable whether piers that would withstand the ice could be built out to deep water from the west shore. Even if such piers could resist the ice they would obstruct its movement, so that ice would accumulate about the piers. Perhaps two piers might be built to form a small inclosed basin.

Icy Bay is therefore not now available as a landing place for the Yakataga district, and it seems doubtful whether the commercial interests to be served will justify the expenditures necessary to make it available. A further recession of Guyot Glacier might bring about favorable changes. The glacier might then no longer discharge bergs. On the other hand, the glacier may advance and the bay may again be closed, so that any improvements would be destroyed.

If Icy Bay is utilized as a harbor a wagon road or railroad must be built from its western shore to the placer and petroleum deposits. Possibly a tramway, for which there is an abundance of timber, would be cheaper than a wagon road. Aside from the bridging of several

glacial streams, whose channels are shifting, such an undertaking would not be difficult.

COOK INLET.

INTRODUCTION.

The supposed oil fields of Cook Inlet are on the west shore. Most of the reported seepages are in an area of Middle Jurassic rocks in the peninsula between Iniskin and Chinitna bays. (See Pl. VIII.) Jurassic beds have been noted in other areas along the west shore of Cook Inlet (see Pl. VII), and oil seepages have been reported from several of them, notably on Douglas River south of Kamishak Bay.

This district lies near the regular steamship route to ports on Cook Inlet. There are no regular ports of call within this district at present, but steamers will call at Tuxedni (Snug Harbor) and Iniskin bays whenever there is sufficient business. The steamers do not go to the head of Cook Inlet during the winter on account of ice. Iniskin Bay is said to be open throughout the year, but Tuxedni Bay is reported[16] to be blocked with ice from December to March. Chinitna Bay is a possible harbor for craft of light draft, and landings can be made at Oil and Dry bays in good weather.

A wagon road runs from the lower landing on Iniskin Bay to the head of Oil Bay, and trails extend from Oil Bay to Dry Bay, to the head of the eastern arm of Iniskin Bay, and to a point 2 miles above the lower landing on Iniskin Bay. Two trails also run from Dry Bay to Chinitna Bay, and a trail runs from the head of Iniskin Bay to the head of Chinitna Bay.

The lowlands north of Iniskin Bay are covered with dense vegetation, about half meadow and half forest. The meadows are deeply grassed and are dotted with groves of cottonwood and thickets of alder and willow. The forests consist of a fair growth of spruce and hemlock. The trees are not large, but many of them are straight and sound. The local supply of timber is probably ample for fuel and for construction during pioneer drilling. South of Iniskin Bay there are no trees except a few small scattered cottonwoods.

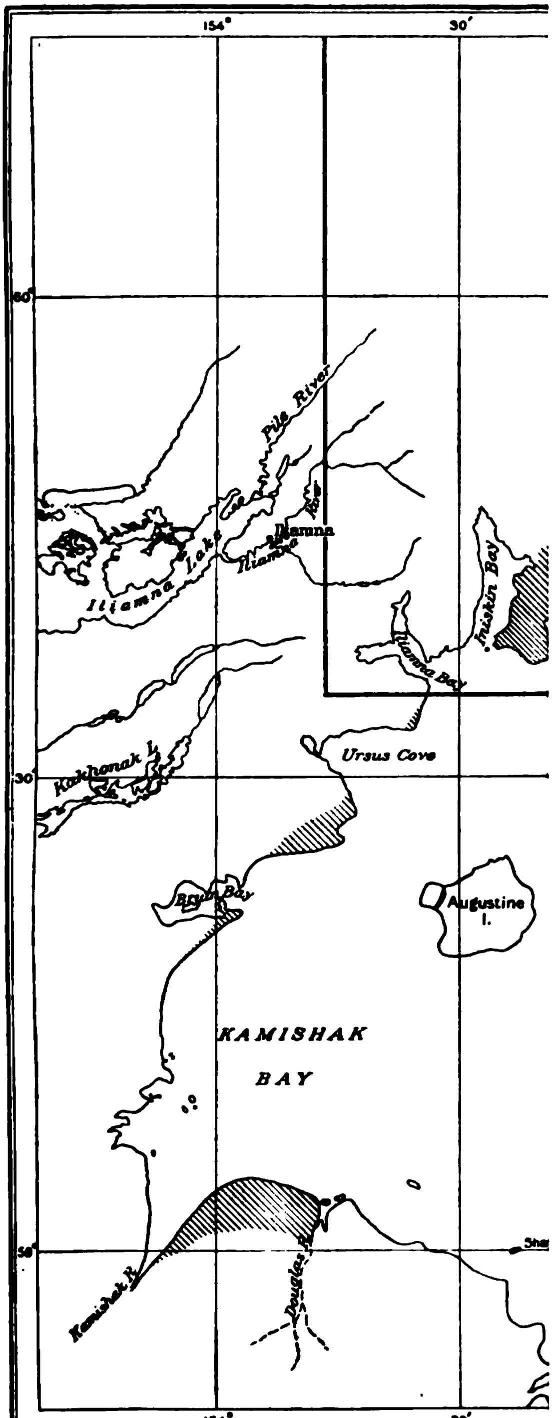
The writer made geologic reconnaissance surveys of the oil fields in 1903 and 1904, the reports[17] on which were subsequently expanded into a more detailed description.[18] These reports are the basis of the description here given.

[16] U. S. Coast Pilot, Alaska, pt. 2, p. 101, 1916.

[17] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 37–49, 1905.

Martin, G. C., Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 133–134, 1905.

[18] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 26–27, 59–74, 95–100, 126–130, 1912.



MAP OF PART OF WEST SHORE OF COOK IN
SEDIMENTAR

GEOLOGY.

GENERAL FEATURES.

The known seepages and the supposed oil-bearing Jurassic rocks from which they issue lie in a belt of foothills and lowlands between the shore of Cook Inlet and the high mountains. The rocks of this belt include unmetamorphosed Mesozoic sedimentary and volcanic strata and, farther east, one or two small remnants of a former fringe of Tertiary beds. The structure is dominantly simple, the Jurassic and Tertiary rocks being but gently flexed and having a general eastward dip, the Triassic rocks alone being complexly folded. The Jurassic strata are believed to be the source of whatever petroleum is present and to be the surface strata in any possible oil fields. The following section shows the general character and thickness of the strata:

General section of Jurassic rocks on west coast of Cook Inlet.

	Feet.
Upper Jurassic:	
Naknek formation (sandstone, arkose, shale, and conglomerate, interbedded with some tuff and lava)	5,000
Chisik conglomerate (tuffaceous conglomerate with shale and sandstone lenses)	300
Chinitna shale (shale with many calcareous concretions and with some limestone and sandstone)	2,400+
Middle Jurassic:	
Tuxedni sandstone (sandstone with some shale, limestone, and conglomerate)	1,500
Lower Jurassic(?):	
Porphyries and tuffs (basaltic and andesitic lavas and tuffs)	1,000?

The rocks of this section overlie or are faulted against Upper Triassic strata that crop out west of them and are overlain unconformably at one or two localities by Tertiary beds; Cretaceous rocks are not present on Cook Inlet.

The Tuxedni sandstone, which rests unconformably upon lavas and tuffs of probable Lower Jurassic age, consists predominantly of sandy beds but contains many thin strata of shale and limestone and at least one bed of coarse conglomerate. Its thickness at the type locality on Tuxedni Bay is at least 1,500 feet, and may be 2,000 feet or more. It contains abundant fossils, a large and highly characteristic marine molluscan fauna ranging through the formation and terrestrial plants having been found in the marine deposits at several horizons.

The Tuxedni sandstone is overlain, probably conformably, by a formation of Upper Jurassic age, which has been named the Chinitna

shale. This formation, which has a thickness of at least 1,300 feet and may reach 2,400 feet, consists of a conformable and fairly uniform succession of fine-grained marine sediments, mostly shale. The Chinitna shale has previously been referred to the Middle Jurassic.

The Chisik conglomerate is a massive plate of coarse conglomerate, consisting of granitic and other crystalline boulders embedded in a tuffaceous matrix. The formation appears to be local rather than continuous in its distribution and to be variable in thickness. The maximum observed thickness is between 300 and 400 feet. This formation rests, without observed unconformity, upon the Chinitna shale and is overlain by the Upper Jurassic rocks of the Naknek formation.

The Naknek formation of the west coast of Cook Inlet consists of sandstone, shale, arkose, conglomerate, andesitic tuff, and probably some andesitic lava. The thickness exceeds 5,000 feet. This formation rests, with apparent conformity, upon the Chisik conglomerate, or, in the absence of the latter, upon the nonfossiliferous shales referred tentatively to the upper part of the Chinitna shale. The original top of the Naknek formation has not been observed on Cook Inlet, the Cretaceous being absent, and the next younger beds being Tertiary and overlying the Naknek formation unconformably.

The dominant structural features of the area occupied by Jurassic rocks on the west shore of Cook Inlet include a fault or zone of faulting, which separates the crystalline rocks of the mountains from the sedimentary rocks of the foothills, and a monoclinal ridge composed of Middle and Upper Jurassic sedimentary rocks which marks the shore from Tuxedni Bay to Iniskin Bay. West of this monoclinal ridge in the peninsula between Chinitna and Iniskin bays the Middle Jurassic rocks are thrown into a series of open folds. A broad, low anticline occupies a lowland area that lies immediately west of the coastal monoclinal ridge. The crest of this fold undulates somewhat and is believed to be cut by one or more faults. The details of the minor folds and of the faults have not been worked out. In the area west of this anticline the rocks are involved in several folds, which become sharper and more irregular as they approach the fault on the border of the mountains. The folds just described were not recognized north of Chinitna Bay and are probably cut off by the fault that marks the eastern boundary of the crystalline rocks of the mountains. In the area north of Chinitna Bay the Jurassic rocks apparently dip uniformly eastward, and this area is regarded as the northward extension of the coastal monocline. The folds described above do not appear on the shore south of Iniskin Bay, where the Jurassic rocks are in general horizontal.

LOCAL DETAILS.

The stratigraphy of the Jurassic rocks in the area between Tuxedni and Iniskin bays has been described in detail by Martin and Katz.[19] The following description gives the available details concerning the structure of that area, as well as some details of the stratigraphy and structure of the coast south of Iniskin Bay.

TUXEDNI BAY.

The rocks exposed on Tuxedni Bay consist of granites at its head, a belt of volcanic rocks farther east, and a belt of Jurassic sedimentary rocks (Tuxedni, Chinitna, Chisik, and Naknek formations) on the lower part of the bay and on Chisik Island.

The volcanic rocks include several types, the interrelations of which are not known. They may include successive flows, flows with intrusive masses cutting them, or either or both kinds of rock brought into their present structural arrangement by folding or faulting, or both. The nature of the contact of the volcanic rocks with the western edge of the sedimentary rocks east of them is not known. One of three possible relations exists: The Tuxedni sandstone, which is the lowest and westernmost of these sedimentary formations, may rest conformably or unconformably upon the volcanic rocks, the two may be separated by a fault, or the easternmost member of the volcanic rocks may locally be a dike younger than the Tuxedni sandstone. The fault relationship is believed to be the most probable. (See p. 46.)

The several sedimentary formations belong in normal, conformable, stratigraphic sequence one above the other in the order of their areal distribution from west to east. In harmony with this sequence there is a general easterly dip on the lower part of the bay. This dip continues without interruption, except possibly between Chisik Island and the point on the mainland west of it, from the westernmost sedimentary outcrop on the western arm of the bay to and somewhat beyond the northern and southern extremities of Chisik Island. There is a western dip on the northern part of the eastern shore of Chisik Island, so the island is, in part at least, synclinal in structure. Numerous small faults and probably several larger ones were observed on the south shore of the bay.

COAST BETWEEN TUXEDNI AND CHINITNA BAYS.

The shore of Cook Inlet from Tuxedni Bay to Chinitna Bay is mostly a low, sandy beach, behind which is a marshy flat. Except at the mouth of Tuxedni Bay, the hills are a mile or two back from

[19] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–74, 77–78, 1912.

the shore. The easternmost of these hills form a monoclinal ridge parallel to the shore. They consist of the rocks of the Naknek formation, having a dip of 10°–30° E.

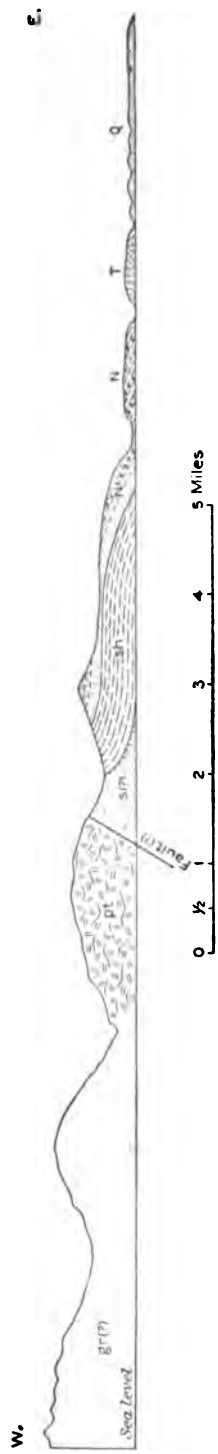


FIGURE 3.—Sketch showing structure on north shore of Chinitna Bay. gr, Granitic rocks (?); pt, porphyries and tuffs; s, Tuxedni sandstone (?); sh, Chinitna shale; N, Naknek formation; T, Tertiary beds; Q, Quaternary deposits.

CHINITNA BAY.

The upper end of Chinitna Bay is at or near the western edge of the presumably Lower Jurassic porphyries and tuffs. These rocks form all the outcrops on the western half of the north shore of the bay. The eastern half has magnificent exposures of the Chinitna and Naknek formations. At the entrance on the north shore is a lone outcrop of Tertiary rocks which is separated from the nearest Jurassic rocks west of it by an interval of sand beach and marsh. The southern shore has outcrops of Tuxedni sandstone near the head of the bay, and of Chinitna shale and Naknek formation near the entrance. Marshy land intervenes between them.

The structural relations of the porphyries and tuffs to the sedimentary rocks east of them could not be directly determined. The fact that westernmost outcrops of sedimentary beds are of the Chinitna shale on the north shore but of the Tuxedni sandstone on the south shore, and that in each case the concealed interval is not large, suggests that this contact is a fault. The concealed interval on the north shore of the bay may contain a narrow belt of the Tuxedni sandstone and is so indicated on the geologic map (Pl. VIII) and on the structure section in figure 3. The presence of a fault is also indicated by the fact that the contact of the Tuxedni sandstone with the porphyries and tuffs has here transgressed eastward in comparison with its position on Iniskin Bay, so that there is on the north shore of Chinitna Bay only one fold between the eastern border of the porphyries and tuffs and the coastal monocline, whereas on Iniskin Bay (see p. 48) there are several folds in this interval.

The exposures of the Naknek formation at the mouth of the bay are part of the

eastward-dipping monoclinal belt which extends parallel to the coast northward to Tuxedni Bay. The dip of the beds of the Naknek formation just within the bay is from 20° to 25° but flattens going westward until, at a point about 3 miles inside the bay, the Chinitna shale exposed on the north shore is almost horizontal. Observations made at a distance from the outcrops suggested that the dip turns westward just before the contact with the volcanic rocks is reached.

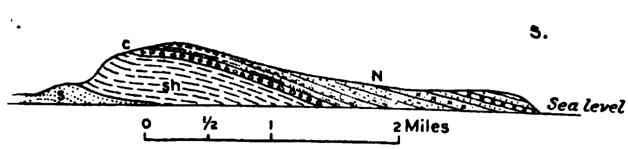
Exposures on the south shore of the bay are lacking between the cliffs at the entrance to the bay and those near its head. Eastward dip was observed at both these points, but conditions farther south indicate that several folds may be present in this concealed interval.

The Tertiary rocks on the north shore of Chinitna Bay near the entrance are horizontal. It may be that the general structure has flattened at this point, and that the underlying Jurassic rocks also are horizontal, or the latter may continue dipping eastward beneath the Tertiary rocks which lie unconformably upon them in the attitude of deposition.

The structural facts observed on Chinitna Bay are presented graphically in figure 3.

COAST BETWEEN CHINITNA AND INISKIN BAYS.

The shore of Cook Inlet from Chinitna Bay to Iniskin Bay consists of rocky cliffs giving clean but not very thick sections of the ssive rocks of the Naknek formation. A range of hills parallel to coast and monoclinal in structure lies close to the shore and con- the Naknek formation on its crest and east side and the Chinitna on its western slope. The dip here, as in the continuation of lge north of Chinitna Bay, already described, is uniformly l. The ridge is broken through by drowned valleys at Dry



—Structure section on east shore of Oil Bay. s, Tuxedni sandstone; sh, Chinitna shale; c, conglomerate; N, Naknek formation.

)il bays. At Oil Bay magnificent exposures of the rocks of the Chisik (?), and Chinitna formations reveal the monoclinal the range, as shown in figure 4. The strike parallels the out the length of this belt, and the dip varies from e steepest observed dip is about a mile south of Chin- dip flattens eastward from the monoclinal ridge, and low point at the entrance to Oil Bay and on the e and Iniskin Bay it is almost horizontal.

INISKIN BAY.

The rocks exposed on Iniskin Bay consist of the presumably Lower Jurassic porphyries and tuffs with intrusive masses on the west and north shores, and of sedimentary Jurassic beds on the east shore. The latter lie in parallel belts consisting successively from north to south of the Tuxedni, Chinitna, Chisik, and Naknek formations. The structural relation of the sedimentary to the older igneous rocks is in part due to faulting, as is shown in figure 5, although at one locality the Tuxedni sandstone was observed to overlie porphyries and tuffs unconformably.

The sedimentary formations are flexed into open folds and are cut by faults. The dips are low and gently undulatory for the greater part of the length of the shore. Several folds are present, of which the most prominent is the monocline, exposed on the lower part of

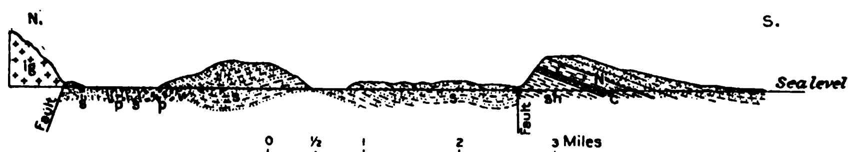


FIGURE 5.—Generalized structure section on east shore of Iniskin Bay. ig, Igneous rocks; s, Tuxedni sandstone; p, porphyry; sh, Chinitna shale; N, Naknek formation; c, Chisik conglomerate.

the bay. This is the southern end of the monoclinal block which has been described above as extending down the coast from Tuxedni Bay. The section in figure 5 is believed to represent the structural details exposed on the east shore of the bay.

URSUS COVE.

The rocks exposed on Ursus Cove consist of the Lower Jurassic igneous rocks on the south shore, the Kamishak chert (Upper Triassic), with its associated igneous rocks and with possibly some older

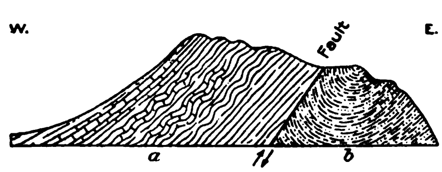


FIGURE 6.—Sketch showing Kamishak chert overthrust upon Naknek formation at mouth of Ursus Cove. *a*, Triassic cherts and limestone; *b*, Naknek shales and sandstones.

limestone, on the greater part of the north shore, and the shale and sandstone of the Naknek formation on the north shore at the entrance. The structural relations of the various igneous rocks to each other and to the Kamishak chert are not known. The Kamishak chert

is strongly folded and appears to lie in a syncline. In its deformation some minor faulting is known to have occurred, and the weaker beds are in places severely contorted. A beautifully exposed fault (see fig. 6) at the north entrance to the cove shows the Kamishak chert overthrust upon the Naknek formation, which is locally folded into an overturned syncline with its axial plane dipping west. This fold either dies out northward or is more probably cut off by the eastward transgression of the fault, for where the latter cuts the shore about 2 miles north of Ursus Cove the Naknek formation is almost horizontal.

COAST BETWEEN URSUS COVE AND BRUIN BAY.

The fault seen at the north entrance to Ursus Cove cuts the shore of Cook Inlet again just south of Ursus Cove and separates the igneous rocks exposed on the south shore of the cove from the Naknek formation, which forms the shore of Cook Inlet almost as far south as Bruin Bay, a distance of about 8 miles. The Naknek formation is practically horizontal where it is exposed on the foreland south of Ursus Cove. The outcrops on a small indentation of the coast known as Rocky Bay consists of about 75 feet of dark-gray shaly sandstone and sandy shale that resemble some of the beds in the upper part of the section on Oil Bay and contain *Aucella* and other fossils (No. 3090). Along the coast between Rocky Bay and the fault contact with the Triassic rocks just north of Bruin Bay there are strata, possibly 800 feet thick, which overlie those seen at Rocky Bay.

BRUIN BAY.

The rocks on Bruin Bay include the Triassic rocks of the Kamishak chert, the Jurassic rocks of the Naknek formation, and some granitic intrusives. The rocks of the Kamishak chert are closely crumpled and cut by numerous small faults. The broader structure of these rocks could not be determined. By the southern continuation of the fault seen at Ursus Cove they are overthrust upon the Naknek formation, which here lies horizontal or is flexed into very gentle wavy folds whose dips do not exceed a few degrees. The granitic rocks are intrusive into the Kamishak chert, having been intruded after the chert was folded. The exposures on the cape at the south entrance to Bruin Bay and in the cliffs for about 5 miles south of this point consist of nearly horizontal beds of dark-gray sandstone and sandy shale belonging in the Naknek formation and having a thickness of at least 500 feet. Neither the top nor the bottom of the formation is exposed, the contact with the adjacent Triassic rocks being a fault. *Aucella* and other fossils (No. 9032) were collected near the entrance to Bruin Bay.

COAST OF KAMISHAK BAY SOUTH OF BRUIN BAY.

The shale and sandstone of the Naknek formation in the cliffs at the entrance to Bruin Bay continue southward in an unbroken series of cliffs for about 5 miles to a place where the great overthrust fault, which has been traced southward, cuts the cliffs and brings up a series of massive or poorly bedded rocks that may be Triassic sediments, but that, as seen from the water, look more like fine-grained homogeneous crystalline rocks. These rocks extend southward to the south end of the cliffs. The shore for 5 or 6 miles south of the end of the cliffs is low and sandy, with no rock outcrops.

At the head of Kamishak Bay horizontal beds of sandstone, shale, and conglomerate of undetermined age appear on the west shore and horizontal beds of the Naknek formation on the east shore. The relations of the two series of rocks were not determined.

The Naknek formation is exposed almost continuously in the cliffs on the south shore of Kamishak Bay for about 10 miles west of the mouth of Douglas River. The exposures are of nearly horizontal buff and gray sandstone, and some beds carry numerous fossils, of which *Aucella* is most abundant. A very striking but apparently not important unconformity was observed near the mouth of Douglas River. The character and relations of the beds at this unconformity are shown in the following section, which was measured by T. W. Stanton:

Section of part of Naknek formation on south shore of Kamishak Bay near mouth of Douglas River.

	Feet.
Gray sandstone with many fossils (No. 3096) in lower part	50
Unconformity.	
Brownish-yellow cross-bedded sandstone, mostly very friable and barren of fossils. Lignitized wood, *Tancredia*, etc. (No. 3097), near top and *Modiola*, etc. (No. 3098), 25 feet above base	100
Gray sandstone, with some masses weathered yellowish brown. *Aucella*, etc. (No. 3099), 70 feet above base and *Tancredia*, etc. (No. 3100), 50 feet above base	75

The total thickness of the Naknek formation along this part of the coast was not determined. The top and bottom of the formation and its contacts with other formations were not observed. The rocks are in most places nearly horizontal and undulate gently, so that only a slight thickness is exposed at the base of the cliffs. Similar horizontal rocks appear to extend inland up to an altitude of 800 or 1,000 feet, there forming the hilltops. The structural relations of these beds to the granites and other rocks south of them in the mountains and east of them on the coast are not known.

PETROLEUM.

SEEPAGES.

The surface indications of petroleum in this region consist of seepages or oil springs and so-called "gas springs." In the seepages the petroleum may be seen oozing from the cracks in the rocks or from the soil. The known seepages are all in the lowlands on the coast of Cook Inlet, most of them between Chinitna and Iniskin bays, where many claims have been staked as petroleum land and several wells have been drilled. The geology and the indications of petroleum in this district have been already described in several reports, from which the facts presented below are taken.

A copious seepage was seen on the east shore of Iniskin Bay, about 1,000 feet below the lower cabin, between high and low tide. The flow is more or less intermittent, and is often so strong that the oil collects in large blotches on the pool or even covers its entire surface. At one point in this seepage the oil was seen issuing from a crevice in the shale of the upper part of the Tuxedni sandstone.

A number of large seepages are reported to be near the cabin at Oil Bay. From the bottom of one of these the petroleum rose almost continually, the flow varying, however, from time to time, now almost ceasing, now becoming very strong. It is frequently possible to skim several quarts of petroleum from the surface of the pool, as was done for the test recorded on page 54.

About 2 miles west of the beach at Dry Bay is a so-called "gas spring," in which gas of unknown composition rises in a continuous stream of bubbles to the surface of the water. From the north shore of Chinitna Bay both oil and gas springs have been reported, but they were not seen by the writer.

All these seepages and gas springs are on the outcrop of the Tuxedni sandstone. Their structural position is a short distance northwest of the monocline described above (pp. 44–48) as extending parallel to the coast. A broad, flat-topped anticline is believed to lie northwest of this monocline, although there is evidence (fig. 5, p. 48) that the structure may be further complicated by the presence of a fault, which marks the northwest edge of the belt of monoclinal dip. The seepages are at or very close to the line on which the dip changes from nearly horizontal to steeply inclined. If the fault extends throughout this belt the seepages are probably on or near it and are intimately related to it genetically.

Seepages are also reported from the shores of Kamishak Bay, especially on the south shore at Douglas River. The rocks in this region, as far as seen by the writer, are the shales, sandstones, and conglomerates of the Naknek formation. They are horizontal or have very gentle dips over large areas.

WELLS.

Indications of petroleum are said to have been discovered in this region about 1853. The first samples were taken out in 1882 by a Russian, named Paveloff. Claims were staked in 1892 by Edelman, near the heads of the creeks entering Oil and Dry bays, but these claims were abandoned. Pomeroy and Giffin staked claims at Oil Bay in 1896, organized the Alaska Petroleum Co. in 1897, and began work in 1898. The first well drilled at Oil Bay is said to have been put down in 1898, but any work done at that date was doubtless merely preparatory drilling. Drilling was also reported[20] at Oil Bay in 1900, but Oliphant[21] says that the well at Oil Bay was started during the summer of 1902, although unsuccessful attempts had been made to land machinery in 1899[22] and to begin drilling in 1901.[23] When the writer was at Oil Bay in August, 1903, the first well was completed and preparations for drilling the second well were under-way.

The first well at Oil Bay is said to have been drilled to a depth of more than 1,000 feet. No log of this well or any other authentic information containing it can be obtained, as the property has changed management several times. According to report gas was encountered all the way below 190 feet, and considerable oil was found at a depth of either 500 or 700 feet. The flow of oil is reported to have been 50 barrels a day, but it may be doubted whether any such quantity was obtained. On drilling deeper salt water under strong pressure was encountered, which shut off the flow of oil. In 1903 the well was said to be more than 1,000 feet deep and afforded a continuous flow of gas, which at times became very strong. Attempts were made to shut off the flow of water and either to recover the lost oil or to drill deeper, but without success.

During the summer of 1904 a second well was drilled at Oil Bay about a quarter of a mile west of the first well. The log of this well, according to Mr. August Bowser, who was in charge of the drilling, was as follows:

Record of well No. 2 at Oil Bay.

Sandstone	200
Shale	120
Oil and some gas	1
Shale (caving)	129
	450

[20] Report of the Governor of the District of Alaska [for 1900], pp. 59–60, 1900.

[21] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1903, p. 691, 1904.

[22] Oliphant, F. H., Petroleum, in Mineral Resources of the U. S. for 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 6 (continued), p. 167, 1901.

[23] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1901, p. 208, 1902 (not in bound volume).

The well was abandoned at a depth of 450 feet, because the shale caved so badly.

During the summer of 1904 a third well was drilled about 250 feet south of the second. The general sequence of strata is reported to be the same as in the second well, the shale continuing to the bottom of the hole. The well was cased to a depth of 630 feet. Oil and gas were reported at a depth of 770 feet, where there were three oil sands, each 6 to 8 inches thick and 4 or 5 feet apart. The output of the well is said to have been about 10 barrels a day. Caving rock was encountered at 830 feet. Work was stopped at a depth of 900 feet at the end of the season. Considerable gas is said to have been encountered, and the pressure at some depths was reported to be strong enough to blow the water up in the derrick to a height of 20 feet.[24]

No information is available concerning operations at Oil Bay in 1905 and 1906. No drilling has been done since 1906, and in 1909 the oil camps were abandoned.

The Alaska Oil Co. was organized in 1901 and began operations at Dry Bay in 1902. The first well at Dry Bay was drilled in the summer of 1902 to a depth of 320 feet without encountering oil. A Star rig was used. The well had a diameter of 8 inches to a depth of 212 feet and of 6 inches to a depth of 320 feet, where the tools were lost and the well abandoned. A second well was started in August, 1903, in close proximity to the first, but not much was accomplished, and work was discontinued a few months later because of an accident to the machinery. No drilling has been done at Dry Bay since 1903.

CHARACTER OF THE PETROLEUM.

A sample of petroleum from the seepage at Oil Bay was collected by the writer by skimming the oil from the surface of the water, where it was continually rising from the bottom of the pool. An effort was made to obtain as much of the fresher oil as possible. Vegetable and earthy impurities were removed by straining through coarse cloth. Water could not be entirely removed. Oil for lubrication at the neighboring wells has been obtained from these pools in this manner.

The fresher oil is dark green. That which has remained on the surface of the pool for some time is dark brown.

The oil has doubtless lost a large part of its volatile constituents, so that the analyses do not represent the composition of the live oil from wells in this region. Such live oil would have a lower specific

[24] Information in this paragraph was furnished by Mr. August Bowser.

gravity, a higher percentage of the more volatile constituents, and a lower percentage of the less volatile constituents, residue, and sulphur. It would certainly be better than these samples in all respects and would resemble them in having a paraffin base and would doubtless be a refining oil.

This sample was submitted to Penniman & Browne, of Baltimore, who return the following report on their tests:

Tests of sample of seepage petroleum from Oil Bay.

	Per cent.	Gravity (°Baumé).
Distillation by Engler's method:		
Burning oil (distillation up to 300° C., under atmospheric pressure)	13.2	29.5
Lubricating oils (spindle oils) (120 mm. pressure, up to 300° C.)	39.2	22.6
Lubricating oils (120 mm. pressure, 300°-350° C.)	19.6	17.9
Paraffin oils (by destructive distillation under atmospheric pressure)	22.4	20.4
Coke and loss	5.6	....
	100.0	
Sulphur	0.098	....
Specific gravity of crude oil at 60° F., 0.9557, or 16.5° Baumé.		
Initial boiling point, 230° C.		

The lubricating oils were distilled under diminishing pressure, according to refinery practice, until signs of decomposition set in. The residue obtained was unsuitable for making cylinder stock and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin—how much it was not practicable to determine with the small quantity of oil tested.

The iodine absorption of the oils and distillates was determined by Hanus's method (solution standing 4 hours) and is here tabulated:

Iodine absorption of oils and distillates from Oil Bay.

	Per cent of iodine.
Burning oil	17.8
Lubricating oil	26.2
Heavy lubricating oil	35.8

For comparison, samples of similar oils were obtained from the Standard Oil Co., and the iodine numbers determined as follows:

Iodine absorption of commercial oils.

	Per cent of iodine.
Light distilled lubricating oil (spindle oil)	32.0
Dark lubricating oil (engine oil)	45.4

The burning oils were tested in a small lamp and found to give a good flame. All the oil was consumed without incrusting the wick or corroding the burner.

The oil has a paraffin base, and the products of distillation are "sweet." We are informed that this sample is a "seepage oil." If a sufficient yield can be obtained by drilling, an oil suitable for refining may be expected, containing a very much larger quantity of the more desirable lighter products.

CONCLUSIONS.

The seepages on the west coast of Cook Inlet, especially those between Chinitna and Iniskin bays, indicate that the Jurassic rocks may contain considerable petroleum.

The results of the drilling are not especially encouraging, but it is said that some oil was found in the wells. (See pp. 52–53.) The wells that have been drilled are too few, too shallow, and were drilled in too small an area to give a final test of the possibilities of the field.

The stratigraphy and structure of certain parts of the district are not unfavorable to the occurrence of oil. The coarse and porous sandstones that contain an abundance of organic remains, especially those in the lower part of the Tuxedni sandstone, may be regarded as possible oil sands and as the probable source of the petroleum and gas that are escaping at the seepages. The areas in which the structure is most favorable for the accumulation of oil include the crest of the easternmost anticline, which extends from Iniskin Bay to Chinitna Bay. Some faulting, however, has occurred on and near the crest of this anticline. The effect of this faulting on the accumulation of oil is not known. No statement can be made concerning possibly favorable localities for drilling in the area west of the crest of the main anticline, except that further investigations may reveal them. In general, however, this western area does not appear to be so favorable as the main anticline, but special localities where the conditions are favorable may be found. The monoclinal belt along the coast, including its northern extension from Chinitna Bay to Tuxedni Bay, and any possible extension into the unsurveyed region north of Tuxedni Bay, must also now be regarded as less favorable for the occurrence of oil. This conclusion is based on the steep dips and on the fact that in most of this area the possible oil sands in the Tuxedni sandstone lie too deep to be reached by the drill. It is possible, however, that favorable areas of gentler dip or higher oil-bearing horizons, perhaps in the Naknek formation, may be found.

Some of the areas occupied by the Naknek formation on Kamishak Bay, especially those in the vicinity of Douglas River, would seem to be more promising prospective oil fields, at least as far as structure is concerned, than the district north of Iniskin Bay, where the wells were drilled. It should be noted, however, that in the known areas of gentle dip along the coast the supposed oil-bearing beds in the Tuxedni sandstone lie so deep that they are beyond the reach of the drill. This part of the coast is, moreover, a very difficult place to land machinery, for the bays are all shallow and filled with rocks, and numerous uncharted reefs extend out many miles from shore.

ALASKA PENINSULA.

INTRODUCTION.

Seepages of petroleum on Alaska Peninsula, especially in the vicinity of Cold and Portage bays and Becharof Lake, have been known for many years. The seepages described as "near Katmai" (see bibliography, pp. 76, 79) are believed to be the seepages between Cold Bay and Becharof Lake. Four wells were drilled near Cold Bay in 1903 and 1904, but no oil has been produced there in commercial quantities, and the camps have been abandoned for many years.

Seepages have also been reported to occur on Aniakchuk River, on the peninsula between Kujulik and Hook bays, on the north end of Chignik Bay, and on the shore of Shelikof Strait about 20 miles southeast of Cape Douglas.

Cold Bay is on the east side of Alaska Peninsula near the west end of Shelikof Strait, nearly opposite the southwest end of Kodiak Island. The bay is roughly triangular, is about 10 miles long and 7 miles wide at its mouth, and includes a large area of deep water. The harbor at Cold Bay is open throughout the year, but it is subject to violent winds and the known anchorages are not very secure. The harbor has not been surveyed, and it is possible that a survey might disclose more satisfactory anchorages and landing places. It is also possible that a survey of some of the neighboring bays might find good harbors.

The surrounding country is an upland that stands in general about 750 feet above tidewater and is surmounted by gently rounded or flat-topped hills. The higher peaks rise to an elevation of about 1,500 feet, but farther back from the coast in the central part of the peninsula there are high mountains. Among these mountains is the volcano Peulik, a peak about 5,000 feet high, which is on the west shore of Becharof Lake about 35 miles west of Cold Bay.

In this district there is no timber that can be used either for fuel or for construction. When the wells were being drilled in 1903 and 1904 derrick timbers and blacksmith coal were imported and the petroleum residue from a local deposit (see p. 64) was burned under the boilers. The only trees are a few small cottonwoods, willows, and alders, which grow along the banks of the streams. The flat lowlands on the shores of Cold Bay are covered with deep grass, but the hillsides and uplands bear no vegetation except moss, scattered tufts of grass, and small growths of brush.

The account of the geology and petroleum given below is based on reconnaissance surveys made in 1903 and 1904. The more important

results of those surveys have already been published,[25] but some details concerning the stratigraphy and structure are here presented for the first time.

GEOLOGY.

GENERAL FEATURES.

The rocks of the Cold Bay district (see Pl. IX) include Upper Triassic shale, limestone, chert, and igneous rocks; Lower Jurassic (?) shale and sandstone; Middle Jurassic (?) sandstone, shale, and conglomerate; Upper Jurassic arkose, conglomerate, sandstone, and shale; and post-Jurassic (chiefly Recent and Tertiary?) volcanic rocks which occur in a belt along the axis of the peninsula. This belt includes several volcanoes, some active and some dormant, among which are Mount Peulik, near Becharof Lake, on the border of the Cold Bay district, and Mount Katmai, a little farther east. Granite and other coarse crystalline rocks are reported from the interior of the Alaska Peninsula and may underlie the Cold Bay district. Cretaceous and Tertiary rocks occur in other parts of the Alaska Peninsula but have not been found near Cold Bay. The main structural features are broad, open folds, whose axes parallel the coast, trending about northeast. The dips of the strata do not generally exceed 15°. Some faults have also been noted.

A number of oil seepages occur in this field, some of which are strong. At one of these seepages there is a considerable flow of gas. The known seepages are on the outcrops of the Upper (and Middle ?) Jurassic rocks, and the oil-bearing beds are believed to be the general equivalent of those of Cook Inlet.

TRIASSIC ROCKS.

Triassic rocks are exposed in Alaska Peninsula, as far as known, only between Cold and Alinchak bays. They form the northeast shore of Cold Bay for at least half a mile inside Cape Kekurnoi and probably extend continuously northeastward along the shore of Shelikof Strait to Alinchak Bay, where they outcrop for at least a quarter of a mile along the southwest shore of the bay and on some of the islands in its mouth.

The exposures at Cape Kekurnoi consist of crumpled limestone and calcareous shale cut by dikes and sills of basalt. Within the bay

[25] Martin, G. C., The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, pp. 50–59, 1905; Notes on the petroleum fields of Alaska: U. S. Geol. Survey Bull. 259, pp. 134–139, 1905.

Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, pp. 393–397, 401–402, 1905.

Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 30–35, 120–124, 1911.

the dip becomes uniformly westward at angles of about 20°, the cliffs exposing a thickness of about 700 feet of limestones and shales similar to those at the cape. Fossils consisting exclusively of *Pseudomonotis subcircularis* (Gabb) are distributed through the upper half of the strata and were collected at several localities (3107) from a quarter to half a mile northwest of the cape. Similar calcareous beds about 100 feet above the highest noted occurrence of *Pseudomonotis* yielded a small collection (No. 3108) of ammonites. A gradual change in the lithologic character of the beds, the rocks becoming less calcareous, begins a short distance northwest of and stratigraphically above this locality. The beginning of this change is regarded as marking the top of the undoubted Triassic rocks. The overlying beds may also belong partly or wholly in the Triassic, but as there are reasons for believing that they may be at least in part Jurassic, and as there is no evidence of a break within them, they will be discussed with the Jurassic rocks on page 59.

The rocks exposed on Alinchak Bay, named in order of age, are basic igneous rocks, contorted cherts, and shales and limestones that contain *Pseudomonotis* (No. 3129). The beds that yield *Pseudomonotis* crop out for about 500 feet along the shore. They differ in dip from place to place, but they are nearly everywhere steeply inclined and at some places reach an angle of 45°. The next exposures are a quarter of a mile farther up the shore and consist of Jurassic or possibly Triassic rocks. (See p. 60.)

The known fauna of the Upper Triassic rocks of Alaska Peninsula consists practically of a single species, *Pseudomonotis subcircularis* (Gabb), which may be the same as *Pseudomonotis ochotica* (Keyserling) of the Triassic rocks of Europe and Asia. This species is characteristic of at least part of the McCarthy shale of the Chitina Valley and has been recognized at many other localities in Alaska. It indicates a horizon corresponding to the uppermost Triassic of California and to the Noric of Europe.

This species has been found on the Alaska Peninsula only in limestone and shale, which are underlain, on Alinchak Bay, by contorted cherts in which no fossils have thus far been found. The stratigraphic conditions are possibly similar to those on the west coast of Cook Inlet, where this same species is abundant in the uppermost shaly and calcareous members of the beds that have been referred to the Kamishak chert, but not in the more massive chert beds below.

JURASSIC ROCKS.

The Jurassic rocks of Alaska Peninsula include the direct southwestward extension of the Jurassic rocks on Cook Inlet and constitute a section which, when fully known, will probably be found to

rival if not excel the section of Cook Inlet in thickness and completeness. Most of the formations and faunal zones at Cook Inlet are now known on Alaska Peninsula, which contains also some Lower or Middle Jurassic strata that are but little known and that are apparently absent on Cook Inlet. The contact of the Jurassic with the Cretaceous rocks is also exposed on the Alaska Peninsula but not on Cook Inlet. The general section of the Jurassic rocks on Alaska Peninsula is as follows:

General section of Jurassic rocks on Alaska Peninsula.

	Feet.
Upper Jurassic:	
Naknek formation (arkose, conglomerate, sandstone, and shale)	3,000-5,000
Upper and Middle Jurassic:	
Sandstones, shales, and conglomerates carrying the fauna of the Chinitna shale	3,800-4,300
Beds of unknown character at Dry Bay and near Becharof Lake with the fauna of the Middle Jurassic Tuxedni sandstone.	
Lower or Middle Jurassic:	
Beds of unknown character at Kialagvik Bay with a Lower Oolite or Upper Lias fauna.	
Lower Jurassic or Upper Triassic:	
Shales and sandstones at Cold and Alinchak bays	2,000?

The Triassic rocks on the northeast shore of Cold Bay (see pp. 57-58) appear to grade upward, with no abrupt change, into less calcareous beds, which do not contain the characteristic Upper Triassic fauna. The change begins about half a mile northwest of Cape Kekurnoi, which is at the eastern entrance to Cold Bay, and the first several hundred feet of strata overlying the known Triassic beds is barren of fossils. Beds of fissile somewhat calcareous sandstone containing ammonites, pelecypods, and plants (No. 3109) (see p. 58) were seen a mile northwest of the cape at a horizon about 700 feet above the highest observed occurrence of Triassic fossils. The general aspect of the ammonites from this locality, according to Stanton, is Jurassic rather than Triassic, but the fossils are unlike any previously known from Alaska. A little farther northwest along the shore, 200 or 300 feet higher, a few more ammonites were collected (No. 3110) and a few specimens of *Rhynchonella* were obtained from a boulder (not in place) on the beach. These ammonites, according to Stanton, include two or three genera of Jurassic aspect and are probably Lower Oolite or older. Another small collection of ammonites and pelecypods (No. 3111) was obtained a short distance south of a large waterfall about 1½ miles northwest of Cape Kekurnoi, about 1,800 feet stratigraphically above

the highest beds containing *Pseudomonotis*. There is a sharp change from sandstone to shale at this place and the dip abruptly changes from 18° to 28°. These changes possibly indicate a fault. The next rocks exposed on the shore northwest of this locality are soft brownish shales several hundred feet thick, above which is a heavy bed of coarse conglomerate. The overlying rocks are apparently Upper Jurassic and will be described on page 61.

These Lower Jurassic (?) rocks probably extend northeastward through the hills to Alinchak Bay, where a collection of ammonites (No. 3130) similar to those of lot No. 3109 has been obtained. The beds that yielded this collection crop out about a quarter of a mile up the shore beyond the Upper Triassic beds containing *Pseudomonotis* (see p. 58) and were not studied in detail. The interval between them and the Triassic exposures is concealed and the beds that overlie them were not observed.

The beds described above include about 2,000 feet of shales and sandstones, which constitute an unnamed formation of problematic age. They apparently overlie the Upper Triassic *Pseudomonotis*-bearing beds conformably, and are either overlain by or are separated by a fault from strata that carry the Upper Jurassic fauna of the Chinitna shale. It is possible that they may, at least in part, represent the highest Triassic, which elsewhere in Alaska was either not deposited or was removed by subsequent erosion. It is also possible that they may include the offshore representatives of the Lower Jurassic volcanic beds of Cook Inlet. Several horizons that are known in Europe between the Rhaetic and the Oolite may here be represented.

Of the few fossils that have been obtained from these beds, neither the marine mollusks nor the plants are sufficiently characteristic for the determination of the exact horizon.

An undescribed Jurassic formation, which has not been observed in the immediate vicinity of Cold Bay but which may outcrop there, and which almost certainly underlies the Middle (?) and Upper Jurassic rocks of the Cold Bay district, occurs on Kialagvig or Wide Bay, where two collections [26] of fossils have been made, although, unfortunately, no description of the rocks containing them is available. The fossils indicate that the rocks at this locality belong in the lowest part of the Middle Jurassic or near the top of the Lower Jurassic series. They certainly belong beneath any of the beds known in the oil fields at Cold Bay or on Cook Inlet, and they are

[26] White, C. A., On invertebrate fossils from the Pacific coast: U. S. Geol. Survey Bull. 51, pp. 64–70, 1889. Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 871, 1896.

possibly younger than the Lower Jurassic (?) rocks exposed on Cold and Alinchak bays.

The presence of the Tuxedni formation on the Alaska Peninsula is indicated by fossils collected on the west shore of Dry Bay and near Becharof Lake. The localities at which these fossils were obtained have not been visited by a geologist, so the occurrence can not be described, nor can even the presence of the formation be positively affirmed.

The oldest rocks of undoubted Jurassic age on Cold Bay are some sandstones, shales, and conglomerates that carry the *Cadoceras* fauna (Upper Jurassic) of the Chinitna shale. The cliffs on the northeast shore of Cold Bay contain a thick section of strata carrying the fauna of the Chinitna shale, but neither the bottom nor the top of these beds has been clearly recognized, for the contacts with the adjacent formations are probably faults. The contact of this formation with the underlying Lower Jurassic (?) shales and sandstones (see p. 60) is about 1½ miles northwest of Cape Kekurnoi. Here the Lower Jurassic (?) rocks are either overlain by or faulted against soft brownish shales, several hundred feet thick, which are overlain by a heavy bed of coarse conglomerate. Above this conglomerate are sandstones interbedded with thinner strata of shale and conglomerate that form the cliffs for about 2 miles and have an estimated thickness of probably 1,000 to 1,200 feet. The fossils contained in lot No. 3106 were obtained from a fine conglomerate near the top of these beds. The overlying rocks are massive sandstones, possibly 1,400 feet thick, overlain by 200 feet of dark shales. Near the top of these shales is a thin band with abundant fossils, as in No. 3105. Above these shales are coarse gray sandstones apparently containing no fossils except *Belemnites* and probably 1,200 or 1,500 feet thick. These beds are separated by a fault from the known Upper Jurassic rock northwest of them.

The following section was measured by T. W. Stanton in the cliffs on the southwest shore of Cold Bay. The base of the section is at Cape Aklek and its top is at Lathrop's store. Neither the base nor the top of the formation is exposed.

Section of part of Chinitna formation on southwestern shore of Cold Bay.

	Feet.
Shaly sandstone with some beds of shale and with *Belemnites*	800±
Coarse gray sandstone with thinner beds of more shaly sandstone and some bands of conglomerate. *Cadoceras*, *Phylloceras*, and *Belemnites* found sparingly from base to above the middle	1,000
Dark shaly sandstone, with some beds of shale and thinner bands and local lenses of conglomerate. *Belemnites* abundant in conglomerate about 100 feet above the base	400

The following section, which was measured by the writer about 10 miles southwest of Cold Bay, shows the character of the upper beds of this formation and the contact with the overlying rocks:

Section of part of Chinitna formation on hillside east of Rex Creek, 1 mile above head of Dry Bay.

	Feet.
Shale and sandstone (overlain by 600 feet of arkose, sandstone, and shale belonging to Naknek formation)	500
Sandstone	90
Argillaceous shale	400
Sandstone, shale, and conglomerate	300

All the rest of the Upper Jurassic rocks now known in Alaska Peninsula have been grouped in the Naknek formation, which is composed of beds of arkose, conglomerate, sandstone, and shale aggregating several thousand feet in thickness and carrying a marine fauna characterized by species of *Aucella* related to *Aucella pallasi* and *Aucella bronni.* The Naknek formation has been recognized at many places on the Alaska Peninsula from the shores of Cook Inlet to Herendeen Bay. It covers large areas, probably being the most extensive of the surface formations, and may be areally continuous throughout the greater part of the length of the peninsula.

The Naknek formation of Cold Bay and vicinity has been described very briefly in a previous report.[27] It consists of arkose, conglomerate, sandstone, and shale, and rests, without observed unconformity, upon the Chinitna formation, as is shown in the following section:

Section of lower part of Naknek formation on east side of Rex Creek about 1 mile above head of Dry Bay.

	Feet.
Arkose, sandstone, and shale	600
Chinitna formation (shale and sandstone, as in section above).	

The thickness of the Naknek formation in the Cold Bay district has not been measured but is probably between 3,000 and 5,000 feet. No overlying formation has been seen.

The best exposures are in the high cliffs along the southwest shore for about 2 miles below the head of Cold Bay. The southern half of these cliffs, according to unpublished notes by T. W. Stanton, is composed mainly of conglomerate, the lower beds being rather coarse, interbedded with coarse sandstone and with some shaly beds. One of the shaly beds near the base of the exposure is several feet thick and contains a few small, indeterminate pelecypods. The beds

[27] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 52–53, 1905.

in this part of the cliff are nearly horizontal and have a thickness of approximately 400 feet. About the middle of the cliff there is a fault, north of which the beds have a much steeper northwesterly dip and contain no conglomerate but a great thickness of shaly and thin-bedded sandstones overlain by more massive sandstone, above which are several hundred feet of dark sandy shales. The total thickness between the fault and the head of the bay is probably 1,500 feet. The fossils contained in lot No. 3102 came from the lower part of these beds.

The Naknek formation is exposed over a large area between the head of Cold Bay and the southeast shore of Becharof Lake. Several collections of characteristic Upper Jurassic fossils were obtained on creeks tributary to Becharof Lake. A large proportion of the rock exposed in this area is conglomerate.

STRUCTURE.

The most striking structural features are an anticline with a northeast-southwest axis extending from a point 3½ miles above the mouth of Oil Creek to Kanata and a syncline extending from a point near the mouth of Oil Creek northeastward into Cold Bay. The north end of this syncline is cut off by a fault which extends up the valley of Dry Creek. The anticline terminates by flattening out.

The dip is rather uniformly northwestward on the north shore of Cold Bay and on the north side of Dry Creek. Along the southeastern side of Becharof Lake it is northwestward and westward. On the western shore of Cold Bay the dip is northwestward or the beds are horizontal. On Dry Bay the dip is southeastward. The dips seldom exceed 15°, except toward the mouth of the bay, and are low and regular over wide areas.

The beds in the region between Becharof Lake and the Becharof-Cold Bay divide have a uniform westward and northwestward dip. This dip is reversed again near the center of the peninsula, so that part of Becharof Lake lies in a syncline, while near its northwestern shore a sharp anticline is said to rise, which brings to the surface not only the entire sedimentary series but also the mass of coarse crystalline rocks. There is also a great anticline parallel to the southern coast that has its axis near the ends of the forelands.

PETROLEUM.

SEEPAGES.

Several seepages occur at the north end of the anticline near the oil wells (see Pl. X), and at all of those seen by the writer the flow of

petroleum is large and constant. One of them furnished lubricating oil for use at the wells, and another produced a considerable flow of gas. Other seepages, not seen by the writer, are reported from different places along the crest of this fold, near the head of Dry Bay, and elsewhere between that point and Kanata. Larger seepages are said to occur on the west shore of the south arm of Becharof Lake.

RESIDUE.

Some of the seepages of petroleum on the hillsides near the oil derricks 5 miles inland from Cold Bay are continuous; others are intermittent. The petroleum runs down the hillsides into the water-courses and collects at the bottom in peat bogs. Losing enough of its volatile constituents by evaporation to become immobile, it remains there, impregnating the peat and forming over its surface a thick coating of black paraffin wax.

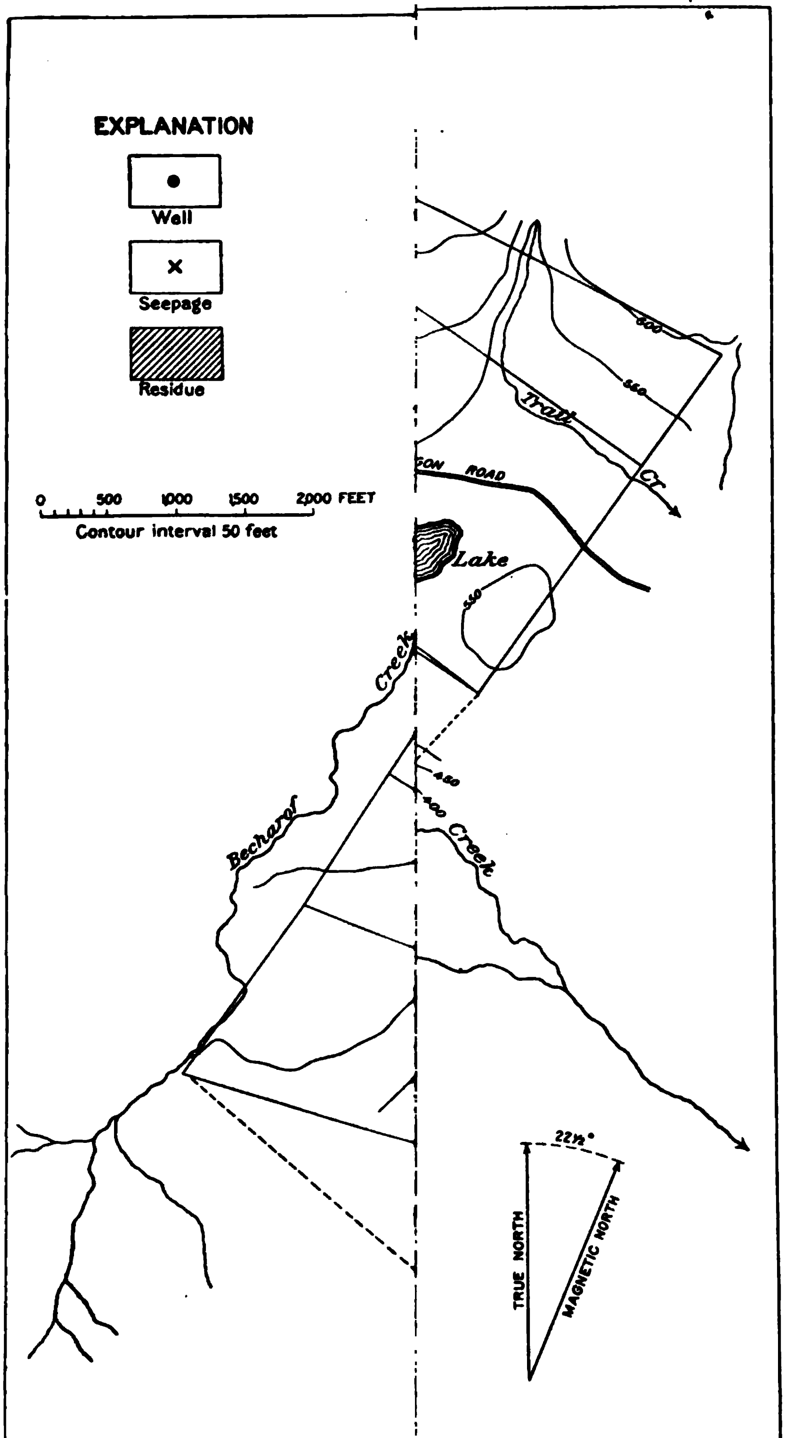
These deposits have already proved most useful in the development of the region, for the peat, impregnated with the paraffin wax, is a fuel of great value, replacing even the coal from the mines of Puget Sound, which was imported for use under the boilers used in drilling. The deposit that furnished this fuel in 1903 and 1904 covers about 3 acres. In some places the material has been dug to a depth of about 3 feet without reaching bottom. Another deposit, which has an area of 3 acres and a thickness of at least 10 feet, has also been discovered in the vicinity, and many more will doubtless be found.

Chemical and calorimetric tests of the petroleum residue have been made by Penniman & Browne, of Baltimore. The result of their tests is as follows:

Chemical and calorimetric tests of petroleum residue.

Moisture	per cent	None.
Volatile matter	do	85.40
Fixed carbon	do	7.76
Ash	do	6.84
		100.00
Sulphur	do	.36
Soluble in gasoline	do	68.20
Heating value	calories	8,193

The test shows a material that compares favorably with most of the coals sold on the Pacific coast. It is, indeed, superior to those in calorific power, ash, and quantity of sulphur. The percentage indicated in the table as soluble in gasoline represents the petroleum residue, the remaining 31.80 per cent consisting of peat and earthy material.


EXPLANATION
Well
Seepage
Residue
0 500 1000 1500 2000 FEET
Contour interval 50 feet
600
550
Tratt Cr
GON ROAD
Lake
550
Creek
Becharof
450
400
Creek
22½°
TRUE NORTH
MAGNETIC NORTH

WELLS.

Drilling in the vicinity of Cold Bay was begun in the summer of 1903 and was continued in 1904. Two companies drilled two wells each. Three wells were begun in the summer of 1903. They are about 5 miles from the landing on the western shore of Cold Bay, at an elevation of about 750 feet above sea level, and are about 9 miles in an air line from Becharof Lake. (See Pl. XI.)

One of the wells drilled by J. H. Costello at an elevation of 780 feet near the headwaters of Oil Creek during the summer of 1903 was abandoned in the autumn, because of a crooked hole, at a depth of 728 feet, and the derrick was moved to a new site a few hundred feet distant. Very little drilling had been done at this point up to the time the writer left Alaska, in September, 1904, but it was reported that the well was only spudded in and reached a depth of 15 feet.

Log of Costello's well No. 1, at Cold Bay.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sandstone	76	76	Soft argillaceous sandstone	15	430
Hard sand with crevices	39	115	Soft blue sandstone with oil	5	435
Sand with hard streaks	85	200	Small showing of oil	45	480
Oil sand, not hard	40	240	Sandstone with streaks of clay	20	500
Sandstone with hard streaks	60	300	Sandstone	120	620
Oil sand, soft	8	308	Show of oil	30	650
Sandstone with hard streaks	82	390	Sandstone	50	700
Oil sand	25	415			

Another well, also begun in 1903, was drilled by the Pacific Oil & Commercial Co., at an elevation of 580 feet, on the divide between Trail, Dry, and Becharof creeks, to a depth of 1,421 feet. The drill is said to have penetrated several strata filled with thick residual oil having about the consistency of warm pitch. This well was finally abandoned in the summer of 1904 because of the strong, continual flow of fresh water. It seems safe to assume that this well is near a fault. This assumption may explain the presence of large quantities of fresh water at all depths and the absence of the more volatile and fluid constituents in the oil. In 1904 the machinery from this well was moved to a new location about 2¼ miles to the southeast, on Trail Creek, and here a well was drilled to a depth of 1,524 feet, where the tools were lost in October of that year.

Log of Pacific Oil & Commercial Co.'s well No. 1, at Cold Bay (elevation, 580 feet).

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	15	15
Gravel	15	30
Blue clay	5	35
Sandstone	103	138
Shale	14	152
Sandstone with showing of oil	19	171
"Slate"	4	175
Sandstone (gas pressure at 204 feet)	62	237
"Slate and shale"	8	245
Sandstone	62	307
Sandstone and shale	4	311
"Slate"	5	316
Sandstone	46	362
"Slate"	3	365
Sandstone	9	374
Limestone	12	386
"Slate"	4	390
Limestone	8	398
"Slate"	5	403
Limestone	28	431
Sandstone (showing of oil at 435 and 445 feet)	31	462
Limestone	10	472
Sandstone	14	486
"Slate"	4	490
Sandstone	22	512
"Slate"	10	522
Sandstone; showings of oil at 522 to 525, 606 to 619, 625 to 630, and 706 to 719 feet, and an increased pressure of gas at 645 feet	228	750
"Oil sand"; oil at 752 to 755 feet	5	755
Shale; showing of oil at 783 to 785 and at 799 feet and increased gas at 785 feet	45	800
Sandstone	37	837
"Slate"	82	919
Sandstone and showing of oil	21	940
"Slate"	7	947
Sandstone and showing of oil	3	950
"Slate"	6	956
Sandstone and showing of oil	7	963
"Slate"	132	1,095
Sandstone and showing of oil	7	1,102
"Slate and shale"	9	1,111
Sandstone	12	1,123
"Slate"	7	1,130
"Slate and shale"	51	1,181
Sandstone	21	1,202
"Slate and shale"; showing of oil at 1,202 to 1,203 feet	8	1,210
Sandstone; showing of oil at 1,314 to 1,321, 1,326 to 1,335, 1,342 to 1,349, and 1,419 to 1,421 feet	211	1,421

Log of Pacific Oil & Commercial Co.'s well No. 2, at Cold Bay (elevation, 175 feet at Trail Creek).

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel	10	10
Sandstone	153	163
Shale	12	175
Sandstone; showing of oil at 262 to 265 feet	98	273
Limestone and shale	17	290
Sandstone	22	312
Sandstone and shale	15	327
Sandstone	153	480
Shale	8	488
Sandstone	20	508
Sandstone and shale	17	525
Sandstone; showing of oil at 857 to 867 feet, steady increase of gas at 950 to 959 feet	434	959
Sandstone and shale	34	993
Sandstone; showing of oil at 1,008 to 1,013 feet, increase of gas at 1,061 feet, and gas and showing of oil at 1,150 feet	549	1,542

The tools were lost in October, 1904.

CHARACTER OF THE PETROLEUM.

A sample of oil from the large seepage at the head of Oil Creek was collected by the writer in 1904. This sample was obtained by skimming the petroleum from the surface of the pools of water, where it was continually rising from the bottom. An effort was made to obtain as much of the fresher oil as possible. Vegetable and earth impurities were removed by straining through coarse cloth. Water could not be entirely removed. Oil for lubrication at the neighboring wells is obtained from these pools in this manner.

The fresher oil is dark green; that which has remained on the surface of the pool for some time is dark brown.

The oil has doubtless lost a large part of its volatile constituents, so that the analyses would not correctly represent the composition of live oil from wells in this region. Such live oil would have a lower specific gravity, a higher percentage of the more volatile constituents, and a lower percentage of the less volatile constituents, residue, and sulphur. It would certainly be better than these samples in all respects and would resemble them in having a paraffin base. It might not be as good as the Controller Bay petroleum but would nevertheless be a refining oil. The sample was submitted to Penniman & Browne, of Baltimore, who returned the following report of their tests:

Report of tests of oil from Cold Bay.

Specific gravity at 60° F	0.9547 (16.6° B.)
Distillation by Engler's method:	
Initial boiling point ° C	225
Burning oil (distillation up to 300° C., under atmospheric pressure) per cent	13.3 (29.6° B.)
Lubricating oils (spindle oils) (120 mm. pressure up to 300° C.) per cent	28.3 (23.8° B.)
Lubricating oils (120 mm. pressure, 300° C.–350° C.) per cent	18.3 (18° B.)
Paraffin oils (by destructive distillation under atmospheric pressure) per cent	32.0 (20.4° B.)
Coke and loss do	8.1
Total sulphur do	0.116

The lubricating oils were distilled under diminishing pressure, according to refinery practice, until signs of decomposition set in. The residue was unsuitable for making cylinder stock, and was therefore distilled for paraffin oils. These paraffin oils contain a considerable quantity of solid paraffin, how much it was not practicable to determine with the small quantity of oil furnished.

The iodine absorption of the oils and distillates has been determined by Hanus's method (solution standing four hours) and the results are tabulated below:

Iodine absorption of oils and distillates.

	Per cent.
Burning oil	17.2
Lubricating oil	27.2
Heavy lubricating oil	35.2

For comparison, samples of similar oils were obtained from the Standard Oil Co. and their iodine numbers determined as follows:

Light distillated lubricating oil (spindle oil)	32 per cent iodine.
Dark lubricating oil (engine oil)	45.4 per cent iodine.

The burning oils were tested in a small lamp and found to give a good flame. All the oil was consumed without incrusting the wick or corroding the burner.

The sample of crude oil from Cold Bay was distilled in such a way as to give the maximum yield of burning oil; under these conditions 52.2 per cent of fair quality burning oil was obtained.

The oils are entirely similar; both have paraffin bases, and the products of distillation are "sweet." We are informed that these samples are "seepage oils." If a sufficient quantity can be had by drilling, an oil suitable for refining, containing a very much larger quantity of the more desirable lighter products, may be obtained.

CONCLUSIONS.

The seepages near Cold Bay indicate that some of the Jurassic rocks there may contain considerable petroleum. The reported seepages between Cold and Portage bays and near Becharof Lake apparently indicate a considerable extension of the possible oil-bearing belt. The character of the Jurassic rocks at Cold Bay, which contain numerous thick, porous beds and an abundance of organic matter, indicates that strata from which oil can be generated and in which it can be stored extend through a considerable thickness of rocks and over a wide area. The structure in parts of the district where the dips are low and uniform appears to be favorable to the presence of petroleum. The dips in a large part of the region do not exceed 10° or 15°, but in some areas the dip is steeper and several faults have been noted. The few shallow wells that were drilled at Cold Bay afforded no conclusive test of the district. Drilling has been restricted to a very small area which probably does not include the more promising part of the district. Certain areas, notably the reported anticlines and zones of seepages between Cold and Portage bays and near the west arm of Becharof Lake, may be worthy of further tests with the drill, but the wells should be located according to competent geologic advice.

Probably other areas on Alaska Peninsula may be at least as promising as the Cold Bay area. In fact, the entire area of Jurassic sedimentary rocks in the peninsula may be worthy of preliminary prospecting, and probably the most promising localities for drilling have not yet been found.

ARCTIC COAST.

Indications of petroleum have been reported from several localities on the Arctic coast and elsewhere in northern Alaska. Petroleum may be found at many places in the Arctic coastal plain, but even if an oil pool were discovered in this northern field the difficulties of transportation would prohibit commercial development except by enormous expenditures. The only available harbors are shallow lagoons that are locked in ice for at least 10 months of the year.

An occurrence of petroleum residue on Smith Bay, about 50 miles east of Point Barrow, has been described by Leffingwell[28] as follows:

At Cape Simpson, on the west side of Smith Bay, there are two conspicuous mounds. The writer has been informed by natives that the northern mound contained a petroleum residue, but, according to information furnished by Stefánsson, this residue is contained in a pool a few hundred yards from the mound. A sample was secured from a keg of the material collected by natives in the employ of Mr. C. D. Brower, of Barrow. It resembles axle grease. An analysis by David T. Day is given below. The deposit is near the seashore, and the natives say that a considerable amount could easily be dug out with spades.

Composition of petroleum residue from Cape Simpson, Alaska.

Water and soluble matter	22
Alcoholic extract (resins and some oil)	8
Naphtha extract:	
Light oil	12
Heavy oil	16
Benzol extract (asphaltic material)	11
Clay and vegetable fiber	29
	98

Another possible occurrence of petroleum is reported on the coast about 300 miles farther east, or about 35 miles west of the Alaska-Yukon boundary, where, according to Leffingwell,[29] "natives report another petroleum mound between Humphrey Point and Aichillik River, near the coast."

It has been stated by Brooks[30] that an oil seepage was discovered in 1914 near Wainwright Inlet, about 130 miles west of Smith Bay, but later information indicates that the discovery was farther east, possibly at the Smith Bay locality.

Another possible indication of petroleum has been found on Colville River, which Stoney[31] described as "a substance called wood by the natives; it was hard, brittle, light brown in color, very light in weight, and burned readily, giving out quantities of gas."

According to Dall,[32] who may have seen either the specimen brought out by Stoney or Stoney's lost original report, the material was possibly ozokerite and was described as

A brown material resembling powerfully compressed peat, recalling pitch in hardness and weight but not brilliant nor disposed to melt with heat but making a clean cut like "plug" tobacco when whittled with a knife. This material was

[28] Leffingwell, E. deK., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 178–179, 1919.

[29] Op. cit., p. 178.

[30] Brooks, A. H., The Alaskan mining industry in 1915: U. S. Geol. Survey Bull. 642, p. 52, 1916.

[31] Stoney, G. M., Naval explorations in Alaska, 1900, p. 69.

[32] Dall, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 818–819, 1896.

sufficiently inflammable to ignite and burn with a steady flame on applying a match to a corner of it, so that in their cold and weary journey it formed a most welcome substitute for wood or other fuel for the camp fire.

Reference to Dall's description of this material was made by Redwood,[33] who said that "from the description there is little doubt that the substance is desiccated petroleum."

The possible occurrence of similar material in the Noatak Valley is suggested in the following statement:[34]

Near the mouth of the Noatak, not far from the camp of August 25, a prospector reported finding a recent deposit of material that he has used as fuel. Specimens from this place show a dark-brown, compact material that burns readily in the flame of a match and gives out considerable smoke and oil but leaves practically no ash. David White, who examined the material, reports that the specimen is composed entirely of large fern spores and resembles the so-called "bogheads." This deposit was not seen in place and no facts as to its extent or relations were learned. If there is enough of it, the deposit should have considerable value as a local fuel.

The possible presence of an oil seepage near Cape Beaufort is indicated by Woolfe's statement:[35] "I have noticed on the shelving banks of a small stream that runs through the coal lands an oil exudation resembling crude petroleum."

The occurrences cited above suggest that there may be petroleum at many places in the Arctic coastal plain, and that possibly there may be a more or less continuous oil-bearing belt extending across northern Alaska. The Arctic coastal plain is composed of nearly horizontal unconsolidated or poorly consolidated Tertiary and Quaternary sediments, which rest in places upon gently folded Cretaceous and Jurassic rocks. The geology of parts of the province has been described by Collier,[36] Schrader,[37] and Leffingwell.[38]

POSSIBILITIES OF PETROLEUM IN OTHER PARTS OF ALASKA.

Petroleum may be discovered in other parts of Alaska, especially in the unsurveyed areas, but the chances of finding it in any of the better-known districts besides those described in this report are very small. In much of Alaska there is practically no hope of discovering oil.

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[33] Redwood, Boverton, A treatise on petroleum, 3d ed., p. 184, London, 1913.

[34] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, p. 153, 1913.

[35] Woolfe, H. D., The seventh or Arctic district: Report on population and resources of Alaska at the Eleventh Census, p. 133, 1893.

[36] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, 54 pp., 1906.

[37] Schrader, F. C., A reconnaissance in northern Alaska, across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne, in 1901: U. S. Geol Survey Prof. Paper 20, 139 pp., 1904.

[38] Leffingwell, E. deK., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, 251 pp., 1919.

The regions that can be definitely excluded from the list of possible oil fields include all the areas of igneous and mineralized rocks in southeastern Alaska; the areas of intrusive, volcanic, and mineralized rocks in the Copper River valley; the areas of metamorphic and igneous rocks of Prince William Sound, Kenai Peninsula, and Kodiak Island; the areas of igneous and mineralized rocks in the Talkeetna Mountains and Susitna Valley; the areas of schists, granites, and other igneous, metamorphic, and mineralized rocks in the Yukon-Tanana region and other parts of the Yukon Valley; and all of Seward Peninsula.

For many years there have been frequent reports of the discovery of oil seepages and gas springs on Prince William Sound and Kenai Peninsula, especially in the vicinity of Cordova and Seward. Most, if not all, of these supposed seepages are in swampy areas and may be caused by decaying organic material in the mud. The geology of all parts of Prince William Sound and of the mountainous parts of Kenai Peninsula is very unfavorable to the occurrence of petroleum or natural gas.

At Seward some interest has been aroused over the discovery of inflammable gas issuing from the mud and water at several localities in the swamps along the railroad. The rocks near these localities, as described by Grant,[38a] are slates that have been metamorphosed and folded to a degree which makes it impossible for accumulations of oil or gas to be retained in them. Although it is reported that a considerable volume of inflammable gas issues from the mud, the writer does not believe that it is other than ordinary swamp gas. The reasons for this belief are (1) that the gas has been seen only in swampy areas where there is an adequate probable source in decaying vegetable detritus, (2) that no accompanying oil has been reported, (3) that no gas has been seen at or near exposures of bedrock, and (4) that the neighboring rocks are so metamorphosed and folded that they can not be considered as a probable source of oil or gas.

Unverified reports of oil seepages on the east shore of Cook Inlet are probably based on the occurrence of gas and scum given off from decaying organic matter in the mud or on iron-stained or sulphurous waters derived from beds of lignite. It is possible but not probable that the gently dipping and poorly consolidated lignite-bearing Tertiary strata on the east shore of Cook Inlet[39] may contain petroleum. If they do, the petroleum may have been derived from underlying Jurassic rocks, and its distribution is probably restricted, irregular, and without any relation to the beds that are exposed at the surface.

[38a] Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 211–212, 217, 1915.

[39] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 67–107, 1915.

Oil claims have been staked near the head of Cook Inlet, near Wasilla and Anchorage, but no indications of oil have been found at these localities, so far as known. The surface exposures in the vicinity of Wasilla and Anchorage consist of Quaternary silts and gravels, which are believed to be underlain either by Tertiary lignite-bearing strata like those of the east shore of Cook Inlet or by slaty rocks like those of the Kenai Mountains. It is possible that swamp gas derived from decaying vegetable material in the mud may have misled someone into believing that there were indications of oil at these localities.

It has been reported that there are seepages at the mouth of Little Susitna River and near Tyonek. The known exposures in the vicinity of the mouth of Little Susitna River are Quaternary silts and gravels. Tertiary lignite-bearing beds are exposed near Tyonek,[39a] but no oil seepages have been seen by any of the six or more Survey geologists who have visited the locality.

At Yakutat and Lituya bays there are Tertiary rocks that may mark an eastern extension of the Tertiary rocks of the Controller Bay and Yakataga districts. The supposed presence of petroleum at Yakutat [40] has caused some excitement, but it is unlikely that seepages were found. Most of the coast between the Yakataga district and Lituya Bay is heavily covered with glacial and alluvial deposits. Oil-bearing rocks may possibly occur beneath these unconsolidated deposits or may protrude through them at isolated localities, but there is no reason to believe that oil will be found at any special localities or that expenditures in search of oil would be justified.

Several oil claims have been staked near Cape Spencer. It is said that several years ago some Indians who worked at the cannery at Dundas Bay brought in a sample of petroleum but refused to tell where it was found. A white man is also said to have reported finding oil in this region. In 1920 several members of the crew of the U. S. S. *Henshaw* found what they believed to be petroleum. They were hunting and found black peat and what they believed to be an oil skim on the surface of a pool. No detailed information concerning the rocks at Cape Spencer is at hand. The only available geologic map[40a] shows this locality included in "Paleozoic limestones, schists, phyllites, and greenstone lavas and tuffs." This map represents a belt of "Tertiary sandstone, conglomerates, and rhyolitic lavas and tuffs" trending toward Cape Spencer, and the supposed seepages may lie in this belt.

[39a] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 95, 187, 1911.

[40] Tarr, R. S., The Yakutat Bay region, Alaska: U. S. Geol. Survey Prof. Paper 64, pp. 169–170, 1909.

[40a] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, pl. 1, 1912.

A large number of oil claims have been staked near Killisnoo, on Admiralty Island. It is not known that seepages have been discovered at this locality. The rocks near Killisnoo include Tertiary coal-bearing rocks and Carboniferous limestones and schists.[40b]

It has been reported that there are oil seepages near Nushagak, in the Mulchatna region, and on the east shore of Andronica Island, one of the Shumagin Islands, but these reports have not been confirmed.

The discovery of oil seepages has also been reported in different parts of the Yukon basin, notably in the Tanana Valley. These supposed seepages, so far as investigated, have all proved to be films of iron oxide, which, especially in combination with marsh gas, simulate seepages of petroleum. Those that have been examined occur in alluvial deposits. Some gas has been encountered in placer mining, where shafts have been sunk below the level of permanent ground frost. As prospectors have been frequently misled by such occurrences into the belief that they had found petroleum seepages, the following note by David White describing simple tests is quoted:

> Among the most important surface indications of the presence of oil and gas deposits are films of oil on water, oil seeps or springs, gas emanations, asphaltic deposits, lenticular accumulations of rock salt or sulphur, and rocks saturated with oil and emitting the odor of petroleum. However, most of these indications should be examined critically with respect to genuineness as well as natural source, especially under certain conditions, and they may require the scrutiny of a specialist in geology or petroleum chemistry. In most of the supposed petroleum seepages the oil-like substance is in reality iron oxide, which commonly forms an iridescent film on the surface of water, especially in marshy places. It can be readily recognized by the fact that it will not burn, and when stirred with a stick breaks into flakes and does not cover the water evenly like an oil film. It also lacks the odor of petroleum; and if a little is put on a piece of muslin and pressed with a hot flatiron, the familiar iron stain is formed. Another simple test for determining the nature of the film is to absorb some of the substance in a blanket or burlap and after allowing it to dry to set fire to it. If the substance is petroleum, it will burn with a long, vigorous flame and will give forth the odor of petroleum.

It was reported in the summer of 1920 that a petroleum seepage had been discovered in the vicinity of Healy Creek, near the southern margin of the Nenana coal field. The rocks in the valley of Healy Creek, according to Capps,[40c] include loosely consolidated sands, clays, and gravels, with beds of lignite underlain by schists and igneous rocks. No petroleum seepages or geologic structure favorable to the occurrence of petroleum were described by Capps or were seen by the writer[40d] in the neighboring part of the Nenana coal field, which was examined in detail in 1916.

[40b] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pl. 33, 1906.
[40c] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pl. 2, 1912
[40d] Martin, G. C., The Nenana coal field, Alaska: U. S. Geol. Survey Bull. 664, 54 p 1919.

There are said to be oil seepages at the locality known as the Palisades or the Bone Yard, on the south bank of the Yukon about 35 miles below Tanana. The strata exposed in the river bank at this locality, according to Collier,[40e] include poorly bedded and unconsolidated silt and gravel containing bones of the mammoth and other mammals, fresh-water and land shells, and vegetable remains which form thick beds "containing wood in all stages of change, from pliable sticks to brittle brown lignite." The lignite from this locality, according to Collier, "is of inferior quality, scarcely changed from wood or peat. Where examined by the writer this peat is mixed with red sand." The supposed indications of petroleum at this locality may be only gases or liquids given off in the surficial decay of the vegetable and animal remains.

Petroleum seepages and "oil shales" have been reported from the upper Yukon Valley, but these reports also have not been confirmed. Some of the less-disturbed areas of Carboniferous and Triassic rocks in the upper part of the Yukon Valley[41] may possibly contain petroleum, but the search for petroleum in this region can not be encouraged until true seepages are found.

The broad areas of Mesozoic rocks in the Kuskokwim[42] and lower Yukon[43] regions may possibly contain areas in which the geologic conditions are favorable to the occurrence of petroleum, but no such areas are now known, and there is no special reason to suspect their existence. The same is true of the areas of Carboniferous and Cretaceous rocks in the Koyukuk,[44] Kubuk,[45] and Noatak valleys. It has been reported[46] that there are indications of petroleum near Nulato, but this report has never been confirmed.

An attempt was made in 1906, according to S. H. Cathcart,[47] to obtain oil at Cape Nome. It is reported that gas was encountered at a depth of 122 feet which blew a 1,200-pound stem 75 feet up the hole. A second hole, 176 feet deep, drilled in 1906, is said to have shown a trace of oil. No further drilling was done until the sum-

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[40e] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 43–44, 1903.

[41] Prindle, L. M., The Fortymile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, 52 pp., 1909. A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, 82 pp., 1913.

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[42] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, 162 pp., 1917.

[43] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, 45 pp., 1914.

[44] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, 88 pp., 1916.

[45] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, 160 pp., 1913.

[46] Oliphant, F. H., Petroleum: U. S. Geol. Survey Mineral Resources, 1902, p. 584, 1903.

[47] Cathcart, S. H., Mining in northwestern Alaska: U. S. Geol. Survey Bull. 712, pp. 196–197, 1920.

mer of 1918, when two wells were drilled with a star drill. The first well was abandoned at 210 feet owing to the loss of a bailer; the second reached a depth of about 150 feet at the end of the season. The hopes of the operators are based upon the supposed gas and oil indications encountered in 1906; upon oil-like films of unknown composition which occur on the lagoons in the neighborhood; and upon a beach foam which is brought in by the on-shore winds and which they suspect to be paraffin. The hard rocks at this locality are granite and schist. Rocks of this kind do not contain oil or gas, and it is believed that any gas which may have been encountered was derived from the alluvial deposits. Petroleum has also been reported near Port Clarence,[48] but it very doubtful whether this report has any substantial basis.

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[48] Redwood, Boverton, Petroleum, 3d ed., p. 184, London, 1913.

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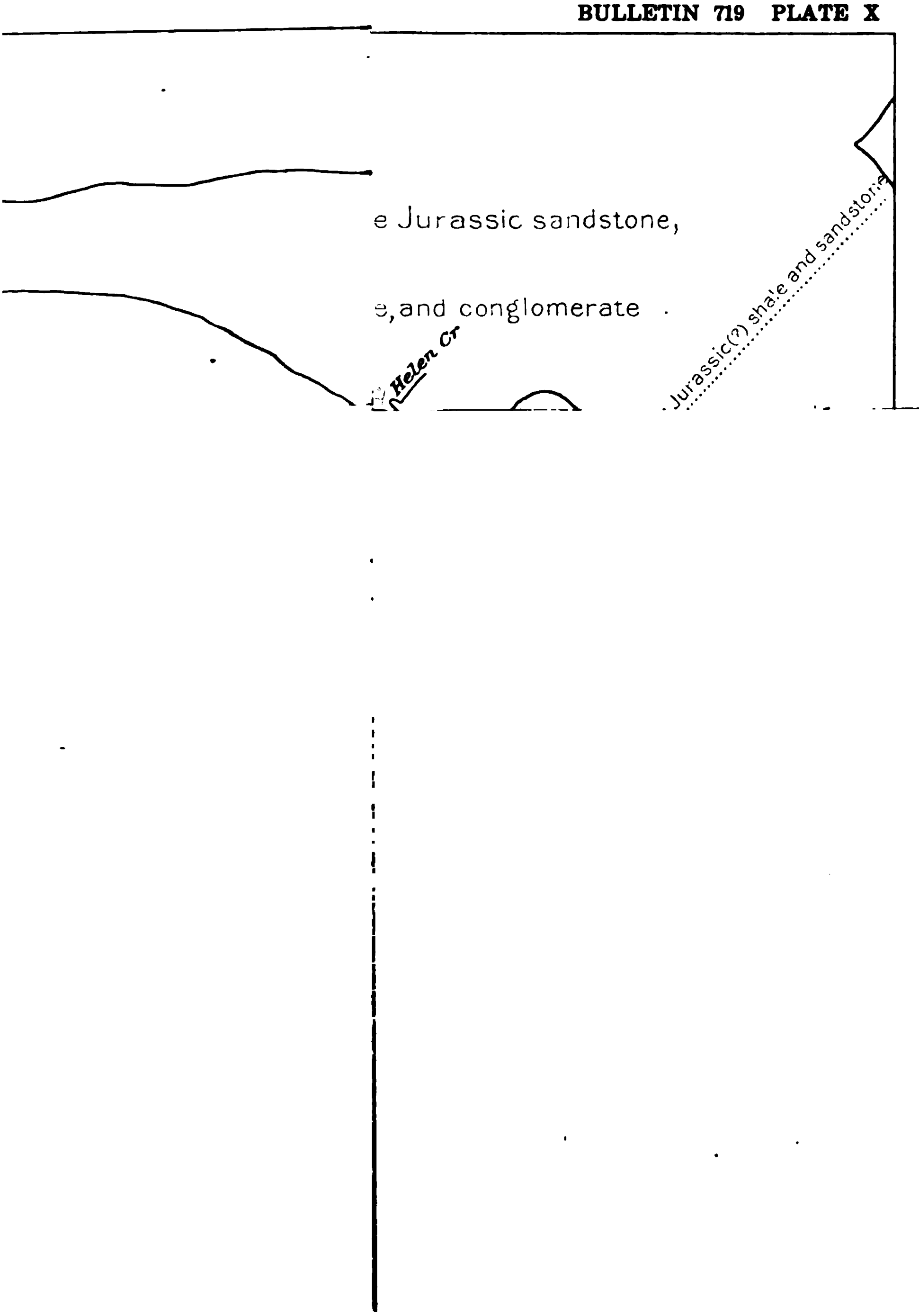
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Jurassic(?) shale and sandstone

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 720

ECONOMIC GEOLOGY

OF THE

SUMMERFIELD AND WOODSFIELD QUADRANGLES, OHIO

WITH DESCRIPTIONS OF

COAL AND OTHER MINERAL RESOURCES EXCEPT OIL AND GAS

BY

D. DALE CONDIT

WASHINGTON
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1923

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ECONOMIC GEOLOGY OF THE SUMMERFIELD AND WOODSFIELD QUADRANGLES, OHIO,

WITH DESCRIPTIONS OF COAL AND OTHER MINERAL RESOURCES EXCEPT OIL AND GAS.

By D. DALE CONDIT.

INTRODUCTION.

SCOPE OF REPORT.

This report describes some features of the economic geology of the Woodsfield and Summerfield quadrangles, in southeastern Ohio. Most of the text consists of detailed information concerning the mineral resources except petroleum and natural gas, which have been described briefly in preliminary reports.[1]

The area covered comprises parts of four counties, all of which contain valuable beds of coal, as well as pools of oil and gas. The western part of the area extends into the Cambridge coal field, and the eastern half includes the Pittsburgh coal bed, which is as yet almost untouched by mining operations and which extends continuously eastward beyond Ohio River into West Virginia.

FIELD AND OFFICE WORK.

The field work on which this report is based occupied a little more than four months during the season of 1914. The members of the party were D. Dale Condit, R. Van A. Mills, Frank Reeves, and for a short time C. A. Bonine. Much of the work consisted in obtaining data for the preparation of a map showing the geologic structure, which involved the instrumental determination of the elevations of limestone and coal beds and of oil-well heads by means of plane table and telescopic alidade. In this work two rodmen were employed. In addition to mapping the geologic structure the members of the party mapped the outcrops of coal beds, limestones, and other strata of prospective value; measured thicknesses in coal mines, prospects, and natural exposures; collected samples of coals and of oil, gas, salt water, and oil sands; and obtained records of hundreds of wells drilled for oil and gas and for the testing of coal beds.

[1] U. S. Geol. Survey Bull. 621, pp. 217-231, 233-249, 1916.

ACKNOWLEDGMENTS.

It is impossible to mention here the names of all the pepople to whom the Survey party is indebted for courtesies and material aid. Special thanks are extended to Prof. F. A. Ray, mining engineer, of Columbus, Ohio; Mr. Edward Christman, specialist in the development of mineral lands, of Massillon, Ohio; Mr. Albert Gaddis, of Uniontown, Pa.; Mr. J. I. Johnson, of Johnstown, Pa.; and Mr. W. A. Clugston, of Pittsburgh, Pa., all of whom have contributed data concerning coal beds. For well records and detailed information concerning oil fields the author is indebted to dozens of persons. Those deserving special credit are Messrs. George Vandergrift, of Woodsfield; G. W. Aggas, of the Pure Oil Co.; M. U. Ward and L. Rawson, of the Carter Oil Co.; J. W. Hardwick and other officials of the Ohio Fuel Supply Co.; T. N. Barnsdale, of Pittsburgh; H. A. Burns, of Chaseville; C. W. Paine, of Ozark; William F. Borchers, of Washington, Pa.; C. B. Barry, of Marietta; Phillip Berry, of Caldwell; H. G. Young, of Sarahsville; Merrit Cox, of Jerusalem; the Larrick Bros., of Pleasant City; and Herbert Howell, of Somerton.

GEOGRAPHY.

LOCATION.

The Woodsfield and Summerfield quadrangles include parts of Belmont, Monroe, Guernsey, and Noble counties, in eastern Ohio. The two quadrangles placed side by side form a rectangular area about 17¼ by 27 miles, which includes about 462 square miles. The east and west boundaries are meridians 81° and 81° 30′; the south and north boundaries are parallels 39° 45′ and 40°. Each quadrangle includes one-sixteenth of a "square degree" of the earth's surface. The location of this and other areas in eastern Ohio and western Pennsylvania covered by geologic reports is represented in figure 1.

Before undertaking geologic investigations such as are the subject of this report the United States Geological Survey makes topographic maps showing surface features, such as hills, valleys, streams, roads, and houses. Maps of this kind have been prepared for all of Ohio. The quadrangles adjoining the Summerfield and Woodsfield are named as follows: On the north, Antrim and Flushing; on the east, Clarington; on the south, Macksburg and New Matamoras; on the west, Cumberland.

The boundaries of the quadrangles have been located exactly from triangulation and plane-table stations situated upon some of the most prominent hilltops of the region, which have been connected by triangulation with astronomical stations at the Maryland Heights and Sugarloaf stations of the Coast and Geodetic Survey, computed

on the United States standard datum. An account of triangulation and primary traverse in Ohio is given in Bulletin 552 of the Survey, and the results of spirit leveling are given in Bulletins 411, 476, and 518. These reports describe bench marks placed by the Survey at many localities and give their exact elevation above sea level.

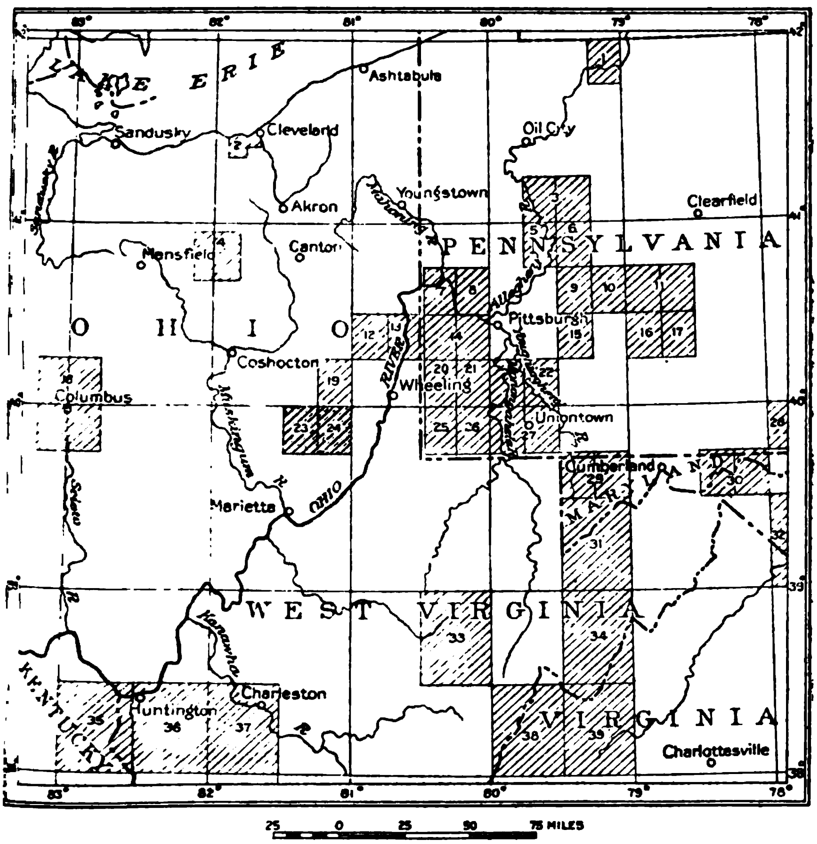


FIGURE 1.—Index map showing location of Summerfield and Woodsfield quadrangles (area indicated by heavy shading) and other areas in eastern Ohio and parts of Pennsylvania, West Virginia, and neighboring States for which geologic reports have been prepared. (See list on p. 6.)

TOPOGRAPHIC FEATURES.

DRAINAGE.

One of the principal water partings of southeastern Ohio extends in a north-south direction across the west side of the Woodsfield quadrangle. The waters east of this divide follow a fairly direct route to Ohio River. The principal streams on the east side are Captina Creek and Sunfish Creek, both of which follow meandering courses in deep, narrow valleys with narrow flood plains and little alluvial bottom land. The gradient is about 23 feet to the mile in

the main valleys, but increases toward the headwaters. It is evident that the streams are actively engaged in deepening their channels, for the stream beds are at many places solid rock. The characteristics of the two principal streams are imparted to dozens of small tributaries, which reach back into the uplands in deeply notched ravines that produce the rough, hilly surface so characteristic of the region.

West of the divide the drainage is carried by branches of Wills Creek, a tributary of Tuscarawas River. A small area at the south side of the Summerfield quadrangle is tributary to Duck Creek and Clear Fork of Little Muskingum River. The broad alluvial valleys of the Wills Creek drainage system form the most striking feature in the region. The sluggish muddy streams flow in meandering courses in swampy valleys that are in places nearly a mile wide—as broad even as parts of the valley of Ohio River to the east. The fall of the principal streams is 2 to 4 feet to the mile, and an only slightly increased gradient prevails in the smaller tributaries almost to their sources. The rock floor of the valleys is in most places many feet below the surface, and the streams flow on sand and clay. It is evident that the entire drainage system was formerly lower, and that for some reason there has been an obstruction to the downward cutting and carrying away of the valley material, resulting in a partial filling of the channels. In fact, there is evidence that the silting up of the valleys filled them to a depth of 100 feet or more above the present level. In Recent time the streams have made considerable progress in removing this material.

The cause of the peculiar aspects of the Tuscarawas drainage system is a physiographic study which can not be undertaken in this report. It is certain that they may be attributed chiefly to events during the glaciation of much of Ohio in Pleistocene time. The river was dammed by the ice front in the vicinity of the present location of Newark, and the ponded waters were forced to seek a new outlet to the south toward Zanesville, along the course of the modern Muskingum River.

RELIEF AND LAND FORMS.

The least elevation at the east side of the Woodsfield quadrangle is about 710 feet above sea level, in Sunfish Valley, and 825 feet in Captina Valley. The valley of Seneca Fork of Wills Creek, at the west side of the Summerfield quadrangle, is slightly less than 800 feet above the sea. West Fork of Duck Creek, at the south side of the area, is about 740 feet above the sea. The highest summits along the principal divide are about 1,400 feet in elevation, giving a relief of about 700 feet for the entire area. The local relief along Sun-

UPLAND LANDSCAPE NEAR SUMMERFIELD.

fish and Captina creeks, which have the deepest valleys, is 400 to 500 feet.

The principal divide extends southward from Barnesville to Lewisville. The ridge dividing the waters of Captina and Sunfish creeks extends eastward across the north edge of Monroe County, and along it are the villages of Malaga, Jerusalem, and Beallsville. The crest of this divide, like those of most other divides in the region, is comparatively even. Extending north and south from it are numerous long parallel ridges that alternate with deep ravines. The elevation of all the ridges ranges from about 1,200 feet to more than 1,300 feet. A few isolated hills of unusual height near Miltonsburg attain 1,400 feet. All the upland has an undulating surface with almost no level areas, but the slopes into many of the smaller valleys are gentle. The alternation of hard and soft strata produces a terraced effect that is evident on almost every hillside. Steep slopes are succeeded by slopes of gentle inclination, suitable for cultivation. An upland landscape near Summerfield is shown in Plate I.

The broad valleys west of the principal divide are bounded by fairly abrupt slopes that terminate in narrow ridges of less altitude and of more rugged contour than those to the east. At the west side of the Summerfield quadrangle, near Senecaville and Lore City, the slight relief is especially noticeable, there being few summits as high as 1,050 feet above the sea. The lower altitude may be attributed to the fact that less durable, more easily eroded rocks make up the surface in that part of the area.

AGRICULTURAL AND COMMERCIAL CONDITIONS.

TRANSPORTATION FACILITIES.

Railroads.—The northern part of the area is crossed by the main line of the Baltimore & Ohio Railroad. From Lore City a branch extends southwestward to Senecaville and Cumberland. These lines are of great importance as coal carriers and will be increasingly so as new branches are built.

The Ohio River & Western Railroad, a narrow-gage line, crosses the southern part of the area. It runs from Zanesville eastward to Bellaire, on Ohio River. This railroad is of chief value as a carrier of merchandise and agricultural products. The route followed takes little account of either hill or valley, and steep grades are so numerous that the line can never be of great importance for the handling of heavy freight.

New railroad routes.—So large a portion of the Woodsfield quadrangle is underlain by coal of demonstrated value that it will in the not distant future be the scene of a great mining industry. There is

some question as to whether railroads can most readily reach the area by the valleys of Captina and Sunfish creeks or from the west up certain valleys tributary to Leatherwood Creek and Seneca Fork of Wills Creek. The approach by the latter route would seem to be the less difficult, there being numerous level valleys offering an excellent grade up to the divide at the west edge of Belmont County, thence through a short tunnel to tributaries of Captina Creek. The crossing of the divide could be made at an elevation somewhat less than that of the railroad at Barnesville, which is about 1,235 feet. Such a route could readily extend eastward from Baileys Mills either up Dog Hollow or Cat Hollow, or up Beaver Creek through Temperanceville.

The principal branches of Captina Creek are fairly straight, but the main stream formed by the union of these branches near the center of the Woodsfield quadrangle follows a devious route eastward that would not favor the construction of a railroad without numerous tunnels, cuts, fills, and bridges. The same is true of Sunfish Creek.

Highways.—The area here considered lies a few miles south of the old National Road from Wheeling to Columbus, which has been for many years an important line of travel. Most of the roads follow the principal ridges or valleys, and therefore the accessibility of many points is largely dependent on the direction of drainage lines. There are only a few miles of improved limestone pike in the area; the longest stretch extends from Barnesville to Malaga. Paved roads lead out a mile or so from Woodsfield in several directions, and short stretches of limestone-surfaced road have been built between Lore City and Quaker City, between Quaker City and Summerfield, and from Barnesville to Baileys Mills. Elsewhere the roads are as a rule unimproved, and any qualities they possess are due to the character of the substrata. The roads that follow sandy ridges are fairly good throughout the year, but the valley roads are almost impassable during the rainy season.

MANUFACTURING AND MINING.

Most of the industries of the area are more or less related to coal mining and the production of oil and gas. The prosperous growth of Woodsfield is attributed largely to its situation in the midst of a number of important oil fields. It contains one manufacturing establishment that specializes in drilling machinery. Barnesville has a glass factory that employs several hundred men, and an establishment that makes coal-mine cars.

Two commercial coal mines are operated in the Pittsburgh coal bed at Baileys Mills, near Barnesville. The Upper Freeport coal is mined by shafting at Blacktop, Senecaville, and Waldhonding, in the western part of the area. Sandstone was formerly quarried at Woods-

field, but the work has been abandoned and no stone quarries are now in operation.

AGRICULTURE.

Notwithstanding the general hilly character of the country, most of it is under cultivation. For a few years after the steep hillsides are cleared of timber they are commonly planted in tobacco. The loss of the soil by wash, however, is so great that the fertility is greatly reduced in a short time, and the ground is then given to grazing or allowed to revert to brush. Where the underlying rocks consist largely of clay and shale landslides are common, and in this way the entire hillside farms are ruined. The region has long been prominent for its sheep and cattle raising. Portions near the mining towns find good profit from gardening and fruit growing.

Not all the extensive bottom land along Seneca Fork and other branches of Wills Creek is productive of good crops each year. The soil is excellent, but the drainage is poor, and floods are frequent. In seasons of heavy rainfall the ground becomes too wet, and in other years the crops, when well advanced, may suddenly be destroyed by floods, which are of common occurrence. On the whole it seems safe to state that the most successful farmers have lands on the hills.

GENERAL GEOLOGY.

STRATIGRAPHY.

All the rocks in this area are of sedimentary origin and exist as more or less continuous beds laid down for the most part in or by water. The outcropping strata consist of sandstone, shale, clay, limestone, and coal, and have a total thickness between 1,100 and 1,200 feet. They are of Pennsylvanian ("Coal Measures") and Permian age and include in ascending order the Conemaugh, Monongahela, and Washington formations as classified by geologists. The dip of the beds is in general southeastward; therefore higher and higher strata are crossed when one travels in that direction. In the valley flood plains and on terraces are unconsolidated alluvium of Quaternary age.

GENERAL SECTION.

The stratigraphy of eastern Ohio has been described in previous reports [2] and only a brief outline is needed here. The several formations represented, with their approximate thicknesses, are listed below. The classification given for the Mississippian rocks is the

[2] Bownocker, J. A., Oil and gas: Ohio Geol. Survey Bull. 1, 4th ser., 325 pp., 1903. Orton, Edward, The stratigraphical order of the Lower Coal Measures of Ohio: Ohio Geol. Survey, 2d ser., vol. 5, pp. 1–300 [illegible]–1058, 1884. Griswold, W. T., and Munn, M. J., Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, W. Va., and Pa.: U. S. Geol. Survey Bull. 318, 196 pp., 13 pls. 1907.

one introduced by the late Professor Prosser,[3] of the Geological Survey of Ohio, for these beds where they crop out in the central part of the State, and the one adopted by the United States Geological Survey. Recent detailed work done by Jesse E. Hyde[4] has, however, led to the proposal of a slightly different classification.

General section of formations in eastern Ohio.

	Feet.
Permian series:	
Washington formation ("Upper Barren")	400±
Pennsylvanian series ("Coal Measures"):	
Monongahela formation ("Upper Productive")	255–275
Conemaugh formation ("Lower Barren")	460–475
Allegheny formation ("Lower Productive")	250–265
Pottsville formation	155–170
Unconformity.	
Mississippian series:	
Maxville limestone (Big lime)	0–110
Unconformity.	
Logan formation (includes Keener sand)	600–700
Black Hand formation (includes Big Injun sand)	
Cuyahoga shale	
Sunbury shale	
Berea sandstone	
Bedford shale [Devonian or Mississippian [5]]	

The Mississippian formations constitute the great oil-bearing rocks of southeastern Ohio and include the Berea, Big Injun, Keener, and Big lime sands, all of which are productive in the Woodsfield quadrangle. In outcrops some 80 miles to the west and northwest the same beds are quarried for building stone. Below the Berea is a great thickness of shale, the bottom of which has never been penetrated by the drill within the Woodsfield or Summerfield quadrangles. The Clinton sand, which yields much oil and gas in central and northeastern Ohio, if present in this region lies more than 4,000 feet below the Berea sand.

The Maxville limestone, known among oil drillers as the Big lime, varies considerably in thickness and is apparently missing in some parts of the Woodsfield quadrangle and much of the Summerfield quadrangle. This is to be expected, for the limestone is variable where seen in outcrop. It is overlain unconformably by sandstone, which forms an undulating contact and locally extends across the limestone, entirely replacing it.

The Pennsylvanian rocks or "Coal Measures" are made up largely of shale, clay, and sandstone, with numerous beds of coal and lime-

[3] Prosser, C. S., Revised nomenclature of the Ohio geological formations: Ohio Geol. Survey Bull. 7, 4th ser., 36 pp., 1905.

[4] Hyde, J. E., Stratigraphy of the Waverly formation of central and southern Ohio: Jour. Geology, vol. 23, pp. 655–682, 757–779, 1915.

[5] The Bedford shale is now regarded by some geologists and paleontologists as of Devonian age. It is at present classified by the United States Geological Survey as Devonian or Carboniferous.

tone. Most of the sandstones are oil bearing at one place or another. The Pottsville and Allegheny formations are below the surface throughout the quadrangles. The Allegheny is the great coal-bearing formation in the northern Appalachain coal basin. In Ohio, though only a little more than 250 feet thick, it includes a number of coal and clay beds of great economic importance. The Upper Freeport coal, which constitutes the uppermost member of the Allegheny formation, lies in the floor of Leatherwood Valley 3 miles west of Lore City and is mined at Blacktop, Klondyke, and other points to the south and southeast. Exposures a few miles to the northwest, beyond the limits of the area here considered, show the Lower Freeport coal, a bed about 1½ feet thick lying about 40 feet below the Upper Freeport. This and other strata are recorded in wells drilled for oil.

The Conemaugh formation was appropriately called the "Lower Barren Measures" by early geologists of the Pennsylvania Survey, for its few coal beds are of little economic importance, and the formation is for the most part made up of shale and irregular sandstone lenses interlayered with clay, which is commonly reddish brown. The formation includes also a few persistent beds of limestone, several of which contain marine fossils. The strata included in the Conemaugh formation lie between the top of the Upper Freeport coal and the base of the Pittsburgh coal, and their thickness is about 450 feet.

The Monongahela formation contains nearly, if not quite, as much coal as the Allegheny. It includes the Pittsburgh, Meigs Creek, Uniontown, and Waynesburg coal beds, all of which are minable within this area. The coals are interbedded with sandy shale, clay, numerous layers of limestone, and a few nonpersistent sandstones.

The Washington formation of the Permian series lacks valuable beds of coal and is characterized by nonpersistent sandstone members, with shale and clay, commonly of reddish-brown color. The few coal beds and thin limestones of the formation are found near the base.

ROCKS AT THE SURFACE.

The rocks at the surface are described briefly below in ascending order. Their general sequence is illustrated by the section (fig. 2), which represents all but the uppermost 200 feet of strata within the area. In another part of this report is given a detailed account of the local stratigraphy in each township.

CONEMAUGH FORMATION.

The Mahoning sandstone, the basal member of the Conemaugh formation, rests directly on the Upper Freeport coal or is separated from it by a few feet of black shale. The sandstone is well known among oil men on account of its yield of oil at Lore City and other

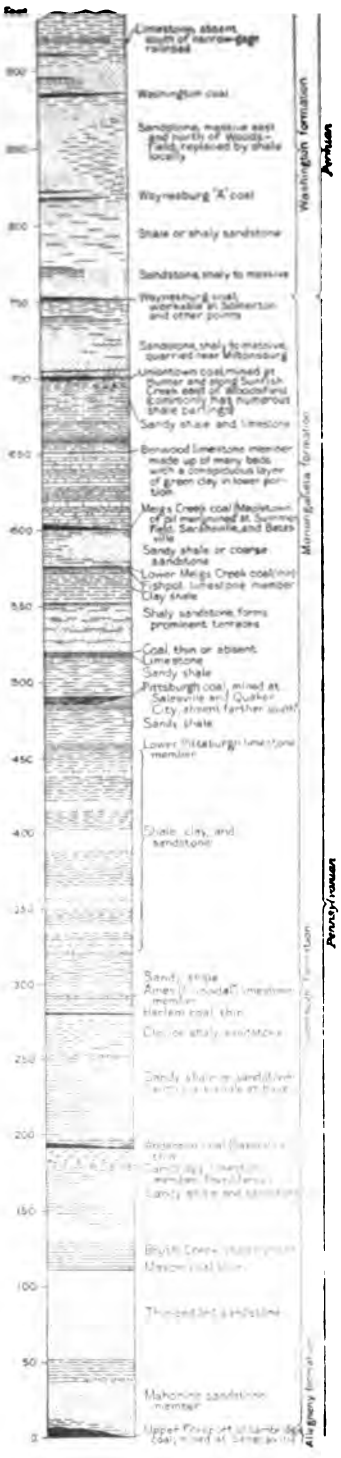


FIGURE 2.—Generalized section of rocks that crop out in the Summerfield and Woodsfield quadrangles.

places to the south. It may be seen in outcrop along Leatherwood Valley, 1 mile west of Blacktop.

The position and character of the members of the Conemaugh formation are shown in the generalized section (fig. 2). Some of the more persistent beds have been named. The fossiliferous Cambridge and Ames limestones are especially noteworthy and serve as excellent key rocks to the geologist. The Lower Pittsburgh member near the top of the formation, is also noteworthy for its persistence. Neither these nor higher strata in the region contain marine fossils. The principal limestone strata are described below.

The Cambridge limestone crops out along valleys in the vicinity of Senecaville and Lore City. Its position is about 175 feet above the Upper Freeport coal. It is a dark gray smooth-textured fossiliferous bed easily distinguished from the other limestones. In numerous places it does not appear as a continuous layer but rather as nodules embedded in clay, and in such places the outcrop is not easily discovered.

The Ames limestone crops out in the northwestern part of the Summerfield quadrangle. It is about 108 feet above the Cambridge limestone and 160 to 190 feet below the Pittsburgh coal. It has a granular texture, is highly fossiliferous, and assumes a greenish-gray to rusty-brown surface on weathering. The freshly broken rock is greenish and shows cleavage faces covered with calcite, and it contains cross sections of crinoid stems which produce the granular texture

A.

B.

LOWER PITTSBURGH LIMESTONE NEAR SARAHSVILLE.

A, Close view, showing pebbly texture; *B*, general view.

From 15 to 20 feet above the Ames and a like distance below it are somewhat similar but less persistent limestone beds, and care is required not to confuse these with the Ames.

About 25 feet below the Pittsburgh coal is a conspicuous limestone member to which the name "Summerfield" was applied by the writer in 1912,[a] but which, being regarded as the same as the Lower Pittsburgh limestone member of the Conemaugh in Pennsylvania, is here designated by the older name Lower Pittsburgh. This rock has a characteristic roughened, lumpy surface that serves to differentiate it from other beds. (See Pl. II.)

The Conemaugh formation is everywhere characterized by the reddish-brown color of certain clay and shale beds in it. This color is particularly prevalent in the strata lying a little below and above the Ames limestone, but it is not uncommonly found in beds locally extending upward almost to the position of the Lower Pittsburgh limestone.

MONONGAHELA FORMATION.

The Monongahela formation includes limestone, shale, sandstone, clay, and coal, aggregating 260 to 280 feet in thickness. Its lower limit is formed by the base of the Pittsburgh coal, and its upper limit by the top of the Waynesburg coal.

The Pittsburgh coal crops out along the valleys west and southwest of Barnesville and also at Temperanceville. Farther east in this area it is 100 feet or more below the surface. It is recorded in nearly all oil wells and has also been tested by core drilling and is known to be present in workable thickness in the greater part of the area. The chief exception is the southwest corner, the limit of the workable coal being, roughly, a line drawn from Temperanceville to Miltonsburg and thence to Lewisville, or possibly to Woodsfield. The rocks at the Pittsburgh horizon are exposed along the valleys of Seneca and Paynes forks south of Temperanceville, but the coal is too thin to be of value.

The Pittsburgh coal is correctly identified by oil men in drilling operations throughout the region, and its position with reference to higher strata is so well established by dozens of hillside measurements and by core-drill and oil-well records that it is chosen as the most convenient key bed for mapping the structure of quadrangles in this part of Ohio.

The Meigs Creek (Mapletown) coal lies 90 to 120 feet above the Pittsburgh bed. The larger interval is unusual and was found only in the region west of Barnesville. Another coal, the Lower Meigs Creek, is found in numerous places in the quadrangle 18 to 35 feet below the

[a] Condit, D. D., Conemaugh formation in Ohio: Ohio Geol. Survey Bull. 17, 4th ser., p. 23, 1912.

Meigs Creek proper. The two coals are commonly separated by massive sandstone. Typical exposures of the lower coal may be seen along Seneca Fork of Wills Creek, where it is mined for local use. It is underlain by a few feet of limestone known as the Fishpot. The Meigs Creek coal lies near the valley floor of Captina Creek for miles eastward from Barnesville, and at the east edge of the area it is a few feet below the bed of the creek. In Adams Township the same coal is a few feet beneath the valley floor of Sunfish Creek and no outcrops were discovered.

Over the Meigs Creek coal is the Benwood limestone, which consists of numerous layers having a combined thickness of about 70 feet. Here and there the limestone is in part replaced by shale or by sandstone in the basal portion. In the vicinity of Summerfield and at other places to the south a conspicuous bed of olive-green clay appears about 16 feet above the Meigs Creek coal. At the same position in outcrops on Captina Creek is a calcareous clay which presents a peculiar checkered surface made up of angular blocks, well illustrated in Plate III, *B*.

From 100 to 120 feet above the Meigs Creek coal is the Uniontown coal, which is useful as a structural key bed on account of its extensive outcrop. Its value for this purpose is somewhat lessened, however, because the coal is in places divided into two beds separated by about 10 feet of shale. The Uniontown coal is mined on Sunfish Creek east of Woodsfield and also on Jakes Run and Bend Fork, tributaries of Captina Creek. (See Pl. IV, *A*.)

Over the Uniontown coal is a sandstone member known as the Gilboy among geologists of the West Virginia Survey. It is prominently developed west of Malaga and Miltonsburg, where it has been quarried.

The Waynesburg coal, like the Uniontown, varies greatly in thickness from place to place and is of no value along much of its outcrop. It also is accompanied by another coal bed 10 feet or so lower.

WASHINGTON FORMATION.

The principal members of the Washington formation are, in ascending order, the Waynesburg sandstone, the Waynesburg "A" coal, a sandstone that occurs at the horizon of the Mannington sandstone of the West Virginia Survey, and the Washington coal. The sandstone correlated with the Mannington of the West Virginia Survey is prominently developed along certain ridges southeast of Barnesville and also eastward from Woodsfield for several miles. (See Pl. XI, *B*.) The Washington coal is persistent throughout the area and has a thickness of 1 to 2 feet. It is locally accompanied by other coal beds, one 10 feet higher and another 26 feet higher. The Washington coal is about 350 feet above the Pittsburgh in Goshen Township, in

A. OPEN-CUT WORKING OF MEIGS CREEK COAL NEAR BETHESDA.

B. STRUCTURE OF CALCAREOUS CLAY NEAR BASE OF BENWOOD LIMESTONE.

A. PROSPECT IN UNIONTOWN COAL BED NEAR HUNTER.

B. SANDY SHALES OVER UNIONTOWN COAL AT WHIGVILLE.

the northeast corner of Woodsfield quadrangle. Toward the south the interval between the two coals gradually increases to about 400 feet at the Belmont-Monroe county line and to 420 feet at the south edge of the quadrangle.

About 40 feet above the Washington coal is a bed of limestone 1 to 3 feet thick which was used as a guide in mapping in Belmont County. To the south, in Monroe County, this limestone is lacking, and in its place is greenish-gray brittle granular clay.

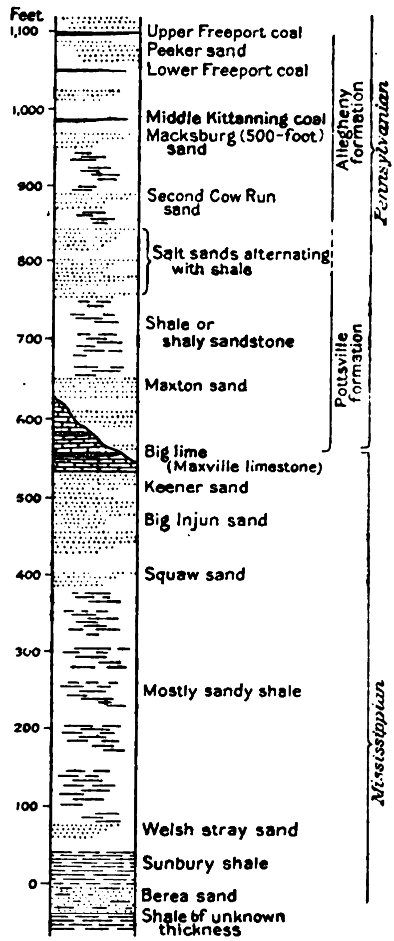


FIGURE 3.—Generalized section of beds below the surface in the Summerfield and Woodsfield quadrangles, with names applied by oil men.

QUATERNARY DEPOSITS.

The unconsolidated alluvial material in the valleys constitutes the youngest bedded deposit in the region. It makes up the flood plains of large and small streams and extends well up to their heads. The material is being constantly cut out and redeposited by variations in the currents at each period of high water.

Some of the deposits within the area may be considered of Pleistocene age, although the region is far removed from the glacial boundary. Many of the branches of Wills Creek valley are partly buried under a considerable thickness of sandy material which fills the rock channel to a depth of 50 feet or more. Traces of similar material are found on terraces and gentle slopes bordering the valleys to a height of more than 100 feet above the present valley floor. Along Seneca Fork in Wayne Township, a few miles southeast of Senecaville, gravel was found at an elevation of about 980 feet, or 160 feet above the valley floor. In the interval of 160 feet between this gravel and the valley are sandy silts in stratified layers lying on the hillsides and effectually mantling the bedrock nearly everywhere.

Along the eastward-flowing streams directly tributary to the Ohio in the Woodsfield quadrangle are rock benches that lie at various elevations, from a few feet to a hundred feet or more above the valleys, and are covered by more or less gravelly material. Each bench is the remnant of a former valley floor which has been almost destroyed in the deepening to the modern valley.

ROCKS NOT EXPOSED IN THE AREA.

Below the surface of this area there are about 2,000 feet of rocks that are fairly well known through evidence furnished by the drill. The Berea sand, the chief objective in the search for oil, lies 1,550 to 1,660 feet below the Pittsburgh coal, and a few test holes have been drilled several hundred feet into the thick black-shale formation beneath the Berea. The general succession of strata below the Upper Freeport coal, with names as applied by oil men, is shown in figure 3. The records of two wells drilled for oil are given below to illustrate the character of the strata below the surface.

Log of well No. 126 (No. 2 on Silas McLoughlin farm), sec. 19, Seneca Township, Noble County.

[Oil well.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Ames limestone	3	45–48	Sand (record incomplete).		
Shale	57	48–105	Sand	20	680–700
Sand	55	105–160	Shale	100	700–800
Fire clay, bad cave (record incomplete).			Sand	20	800–820
Sand	55	275–330	Shale	47	820–867
Fire clay	10	330–340	Sand, Keener (show of oil at 878 feet)	143	867–1,010
Sand	10	340–350	Shale	15	1,010–1,025
Shale	15	350–365	Sand, Big Injun	10	1,025–1,035
Coal marker		368	Shale	391	1,035–1,426
Sand, show of gas	62	368–430	Berea sand (oil at 1,432 feet).		
Shale	45	430–475	Total depth	....	1,436

Log of well No. 372 (No. 1 on Martha Mobley farm), sec. 31, Adams Township, Monroe County.

[Gas well.]

	Thickness.	Depth.
	Feet.	*Feet.*
Conductor	....	0– 9
Coal	3	167– 170
Coal (Pittsburgh)	4	504– 508
Red rock	100	600– 700
Lime	50	700– 750
Red rock	75	750– 825
"Slate"	45	825– 870
First Cow Run sand	20	870– 890
Second Cow Run sand	185	950–1,135
"Slate"	115	1,135–1,250
First salt sand (water at 1,280 feet)	60	1,250–1,310
Lime	10	1,310–1,320
Second salt sand (water, 1½ barrels an hour, at 1,335 feet)	65	1,320–1,385
"Slate"	15	1,385–1,400
Maxton sand	50	1,400–1,450
"Slate"	30	1,450–1,480
Big lime	....	1,480
Keener sand (scum of oil at 1,586 feet; water rising 200 feet in 3 hours at, 1,591 feet; water, 1 barrel an hour, at 1,615 feet)	33	1,582–1,615
"Slate"	10	1,615–1,625
Big Injun sand (little dark oil and gas at 1,665 feet)	175	1,625–1,800
"Slate" and lime	115	1,800–1,915
Welsh sand, limy	75	1,915–1,990
Berea sand (gas at 2,163 feet)	10	2,160–2,170
Total depth	....	2,179

STRUCTURE.

DEFINITION OF STRUCTURE.

The rocks throughout most of eastern Ohio as viewed in outcrop appear to lie level or so nearly level that the inclination is not noticeable to the eye. Anyone who has been in a coal mine, however, will remember that the floor is generally far from level and slopes up and down with considerable irregularity.

When by means of instrumental leveling numerous observations are obtained along the outcrop of a coal or limestone bed and its "lay" or attitude is thus determined, it will be found to slope in various directions and at an ever-varying rate from place to place. The term "structure" is used by the geologist to designate such changed positions of rock beds from the nearly horizontal one in which they were originally deposited.

APPALACHIAN TROUGH.

The rocks of southeastern Ohio form the west side of the Appalachian trough, a great shallow structural basin lying between the Allegheny Mountain front and the Cincinnati arch. The general direction of dip is southeastward at a gentle rate, averaging about 20 feet to the mile. The bottom or axis of this trough is a little east of Ohio River, and east of it the rocks rise across West Virginia. The slopes of this basin are far from uniform and are traversed by numerous minor wrinkles that form anticlines and synclines. These are very insignificant when the basin is considered as a whole but are of great economic importance because of their influence on the accumulation of petroleum and natural gas.

FIELD METHODS IN STRUCTURAL STUDY.

Various methods are employed by geologists in the study and mapping of geologic structure. An instrument commonly used but not suited to the most refined work is the aneroid barometer. This is serviceable where extreme accuracy is not required, especially if the region has a well-distributed set of bench marks showing the elevation above sea level at numerous points. Where greater accuracy is desired, surveying instruments for leveling and stadia traverse are recommended. In carrying on the work in the Summerfield and Woodsfield quadrangles the Gale alidade was the principal instrument used.

The area is favored with a number of persistent, easily recognized limestone and coal beds which serve as excellent key strata for the determination of structure. Elevations at about 2,000 points along the outcrops of the strata were obtained, and hundreds of measurements of the intervals between the beds were made in ravine and

roadside exposures. These data were supplemented by others obtained from records of oil wells and coal test holes, and thus the intervals between the key strata throughout the area were accurately determined. With elevations on the key strata in every square mile of the area and information as to the relation of these beds to one another it was easy to reduce the observations to one datum by addition or subtraction of the appropriate interval. The Pittsburgh coal forms the most convenient datum and is generally used in structural mapping wherever it is present in southeastern Ohio and adjacent parts of Pennsylvania and West Virginia.

The variations in interval between some of the important key strata and in their positions with reference to the Pittsburgh coal are tabulated below.

Intervals between principal strata.

Pittsburgh and Washington coal beds.

	Feet.		Feet.
Hunter, Goshen Township	355	Lewisville[7]	386
Somerton	378	Woodsfield	415
Malaga	393	Junction of Piney Fork and Sunfish Creek	416
Beallsville	398		

Pittsburgh and Waynesburg coal beds.

	Feet.		Feet.
Temperanceville	265	Hunter	263
Somerton	277	Summerfield	273
Newcastle	268		

Pittsburgh and Uniontown coal beds.

	Feet.		Feet.
Barnesville	206	Malaga	220
Temperanceville	215	Junction of Piney Fork and Sunfish Creek	230
Hunter	205		

Pittsburgh and Meigs Creek coal beds.

	Feet.		Feet.
Hunter	87	Calais	113
Barnesville	108	Mount Ephraim	116
County line west of Barnesville	120	Sarahsville	116
Temperanceville	111	Summerfield	117
Malaga	87	Junction of Piney Fork and Sunfish Creek	98
Wayne Township, Belmont County, east side	105	Beallsville	98

Upper Pittsburgh and Lower Pittsburgh limestones.

	Feet.		Feet.
Quaker City	23	Summerfield	24
Temperanceville	22		

[7] There is some doubt as to the accuracy of this figure because the identity of the coal at Lewisville as the Pittsburgh is not certainly established. It may possibly be the Pomeroy, a rider coal 25 to 35 feet above the Pittsburgh.

Pittsburgh coal and Ames limestone.

	Feet.		Feet.
Chaseville	175	Kennonsburg	190
Gibson station	190	Riches School, 3 miles north of Sarahsville	159
Salesville	186	Sarahsville	192
Quaker City	188		

Lower Pittsburgh limestone and Lower Meigs Creek coal.

	Feet.		Feet.
Sarahsville	115	One mile west of Calais	110
One mile south of Kennonsburg	120	One mile southeast of Mount Ephraim station	124
Two miles southwest of Batesville	117		

Ames and Cambridge limestones.

	Feet.		Feet.
Blacktop	109	Senecaville	107
Waldhonding mine	108		

Ames limestone and Upper Freeport coal.

	Feet.		Feet.
Blacktop	275	Senecaville	265

It is evident from the above data that there is considerable variation in the interval between beds from place to place. This is true of limestone beds as well as of coal.

DELINEATION OF STRUCTURE.

After the elevations on key strata have been reduced to the Pittsburgh coal datum, the contour map (see Pl. XII, in pocket) is drawn to illustrate the structure of that bed. The method is illustrated in figure 4, which shows elevations above sea level at a number of points of outcrop. The contour lines are drawn at vertical intervals of 10 feet through points of equal elevation in the manner illustrated in the diagram.

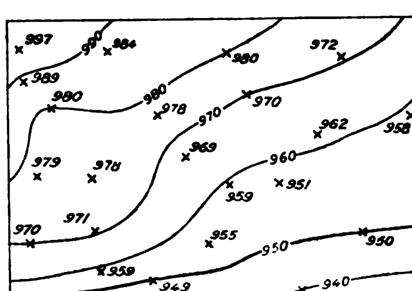


FIGURE 4.—Diagram illustrating method of drawing structure contours.

The accuracy of structure contours in expressing the "lay" of a coal bed depends on several factors. The elevations must be taken at points not too widely spaced, else they will fail to disclose numerous minor flexures. More or less error is inevitable in the reduction of elevations of different key strata to terms of the bed which is being used as a datum, because the interval between beds varies from place to place owing to the irregularities of the surface on which each bed was deposited.

USES OF STRUCTURE CONTOUR MAP.

The structure contour map is an important aid to prospecting for petroleum and natural gas, and its value is generally recognized by oil men.[a] Aside from this use, such a map is of service to the coal miner in selecting favorable locations for mine shafts and drift mine openings. At one locality in the Woodsfield quadrangle the Pittsburgh coal dips eastward as much as 80 feet in 1 mile, and at another locality it dips at a similar rate toward the southwest. In the selection of a location for sinking of a shaft to be used for hoisting coal the operator may wish to place it near the lowest point on the coal bed on the property. He will be able to make an intelligent choice by consulting the structure contour map. The same use is applicable in opening drift mines. The farmers have learned from experience to open mines on the south or southeast side of the hill in order that the water may drain readily. This rule is usually a safe one on account of the general southeasterly dip, but there are numerous local exceptions that only structural mapping will bring out.

Of course, the contours on the base of the Pittsburgh coal can readily be used to determine its depth below the surface at any point. For instance, the bed is shown to be 640 feet above sea level at the mouth of Piney Fork, 5½ miles east of Woodsfield. The surface of the valley at that point is about 775 feet above sea level, and therefore by subtraction the depth of the bed is shown to be 135 feet below the surface. In like manner the map may be used in calculating the depth below the surface of other coal beds whose positions with reference to the Pittsburgh coal are known.

SALIENT STRUCTURAL FEATURES.

The general southeastward dip of the strata is evident from an inspection of the map (Pl. XII). At the southeast corner of the Woodsfield quadrangle the position of the Pittsburgh coal is about 600 feet above sea level. The northwest rise brings it to an elevation of 1,000 feet at Barnesville, 1,080 feet at Quaker City, and 1,200 feet at the northwest corner of the Summerfield quadrangle. The elevation last named is the position at which the coal would lie in case the hills west of Lore City were high enough to contain it.

The term "strike," as used in the geologic sense, means the direction of a line drawn along the outcrop of any rock stratum at a right angle to the dip. Therefore, each contour on the structural map shows not only the elevation of the coal, but also its strike. The numerous local variations from the general northeasterly direction followed by the contours represent minor folds or cross flexures that

[a] See U. S. Geol. Survey Bull. 621 for structural maps of the Berea oil sand in the Summerfield and Woodsfield quadrangles.

give structural forms of various shapes for which the appropriate terms are "terrace," "nose" or "promontory," "embayment" or "trough," "synclinal basin," and "anticlinal fold." True anticlinal folds or arches in the strict sense of the term are few in this area, and there are only two such folds of any prominence—one near Barnesville, which contains the Barnesville oil and gas pool, and the other at Chaseville, which yields oil and gas. In these folds the axis or crest line slopes or pitches both to the northeast and to the southwest from a point that may be designated the summit of the fold.

At Lore City and at two points south of Barnesville are synclinal basins or troughs, the opposite of the anticlines in structure. Another depression of similar character is situated at Woodsfield. The rocks slope into the center of these basins from all sides, thus giving them a saucerlike form.

One illustration may be given to explain the method of interpreting structure by means of the coutour map. It will be noticed that the contours are far apart for a distance of a mile or so to the south and east of Temperanceville. As each contour interval represents a difference of 10 feet, it is evident that the rocks lie nearly flat at that locality and rise gently west of the village. The almost flat terracelike structure at Temperanceville is succeeded eastward by an abrupt increase of dip to more than 80 feet to the mile, which continues as far as the shallow depression southwest of Somerton. East of the depression the strata are nearly flat, but farther east they show an increased downward slope toward Malaga and Newcastle and in other directions.

On the map (Pl. XII, in pocket) are drawn the axes of the principal folds, including anticlines, synclines, and cross flexures, most of which pitch in a south to east direction. Practically all these folds begin and end in the area and are only a few miles in extent.

SUMMARY OF ECONOMIC GEOLOGY.

COAL.

STATISTICS OF PRODUCTION.

In the mining of coal in eastern Ohio for railroad shipment the most extensive operations are in the Pittsburgh and Upper Freeport beds. The Lower Freeport ranks next in importance, and is mined at Amsterdam and other places in Harrison, Jefferson, and Columbiana counties. The Meigs Creek coal has been mined in a large way only at Flushing, in Belmont County. The Pittsburgh bed, the most extensive of all, is mined chiefly in the northeastern part of Belmont County, where transportation facilities are good and where the bed is accessible by drifts or by shafts of slight depth. The

following table shows the production of coal for a number of counties in eastern Ohio through a period of years:

Coal produced in certain counties of eastern Ohio, in short tons.

County.	1890	1900	1910	1911	1912	1913
Mahoning	256,319	46,462	60,434	52,748	33,194	15,786
Columbiana	567,595	692,264	715,252	660,196	448,778	522,804
Jefferson	491,172	1,110,586	5,241,681	4,687,731	4,858,529	5,178,922
Harrison	8,600	6,342	560,937	559,267	812,953	730,221
Stark	836,449	1,116,524	496,509	450,256	414,452	417,238
Carroll	328,967	167,521	313,517	269,167	322,969	379,064
Guernsey	413,739	1,852,327	4,686,994	3,896,682	4,246,955	4,321,992
Belmont	774,110	1,345,284	8,265,019	8,092,127	9,382,330	10,436,259
	3,676,951	6,337,310	20,340,343	18,667,174	20,520,160	22,002,298

County.	1914	1915	1916	1917	1918	1919
Mahoning	15,903	12,556	19,073	42,028	34,451	50,681
Columbiana	342,366	541,862	589,527	566,317	673,271	634,411
Jefferson	2,172,881	3,608,453	5,532,929	5,597,720	6,689,936	5,030,419
Harrison	184,892	214,630	973,628	1,216,253	2,070,414	1,427,972
Stark	457,933	352,020	296,381	373,222	533,591	387,074
Carroll	235,480	344,966	301,137	432,827	451,024	344,626
Guernsey	2,936,707	3,232,961	4,386,161	3,949,852	4,298,812	3,334,973
Belmont	2,849,181	4,304,566	10,330,941	11,166,504	11,852,508	10,101,682
	9,195,343	12,612,014	22,429,777	23,344,723	26,604,007	21,311,838

COAL BEDS IN STRATA THAT DO NOT CROP OUT IN THE AREA.

Here and there in the Woodsfield quadrangle and especially in the Summerfield quadrangle coal beds lower than the Upper Freeport have been noted in the drilling of oil wells. Most of the reports have come from the vicinity of Quaker City and Salesville from the Summerfield gas field, and from the area between Sarahsville and Senecaville. A coal commonly recorded is probably the Lower Freeport, which lies about 40 feet below the Upper Freeport and is generally less than 2 feet thick where seen in outcrop to the west, in the vicinity of Cambridge. Both this and lower beds recorded by the driller may prove of value on further investigation, but it must be borne in mind that the churn drill is at best a crude apparatus for coal testing, giving little reliable evidence as to composition or thickness. The same coal tested by the core drill might prove to be only "bone" or shaly coal of little value. Some of the reported occurrences of deep-lying coal beds are mentioned in the township descriptions.

UPPER FREEPORT COAL BED.

The western part of the Summerfield quadrangle includes the east border of the Cambridge coal field, the most valuable area of the Upper Freeport bed in Ohio. Cambridge, the principal city in the region, is at the north edge of the field, and to the south as far as Caldwell, a distance of 20 miles, commercial mines are distributed

on and near the Cambridge & Marietta branch of the Pennsylvania Railroad and the Cumberland branch of the Baltimore & Ohio Railroad. Commercial mines are in operation at three places in the area here described—Blacktop, Senecaville, and Waldhoning.

All mining operations are preceded by careful exploratory testing by the diamond drill or the hollow-rod drill, for the reason that the coal, although 6 to 7 feet thick in large areas, is subject to abrupt changes in thickness. The Mahoning sandstone, which lies above the coal, is ordinarily separated from it by a few feet of black shale, but here and there the sandstone extends downward, forming an undulating contact with the coal and locally even replacing the coal throughout large areas.

The uncertainty of the bed and the failure of the companies to furnish records of all the test holes makes it impossible to give any information as to the acreage of the bed. Most of the exploratory work has been carried on near the principal mining centers, in outlining the limits of minable coal on the property of each company. The locations of most of the test holes are represented on the accompanying map (Pl. XII, in pocket) and also on the farm map in an earlier report.[a] At many places the bed is limited by sandstone "rolls." The Upper Freeport coal bed is probably at its best in a large area of proved coal land east and northeast of Senecaville. South of this area the coal bed is, according to information obtained in the drilling of oil wells, broken by sandstone rolls and in places seems to be absent. In most of the area of the Chaseville oil pool the coal is lacking. The same is true in the vicinity of Sarahsville, as indicated both by oil-well drilling and hollow-rod test holes. The information available for the area south of Sarahsville does not indicate commercial quantities of the Upper Freeport coal.

Records of nearly all oil wells in the area south of the railroad between Sarahsville and Summerfield show no coal at this horizon. In a few wells drilled north of Summerfield a coal bed that may be the Upper Freeport has been recorded. Of course, the failure of the driller to mention coal in the well record does not necessarily mean that no coal beds were encountered. Numerous records, however, mention certain thin coal beds other than the Upper Freeport, and it is taken for granted that in the places represented by these and other records that are fairly detailed the Upper Freeport bed is not present.

For information as to the thickness of the Upper Freeport coal in the several mines in the area the reader is referred to the descriptions given under Richland, Center, and Wills townships, Guernsey

[a] Condit, D. D., Structure of the Berea oil sand in the Summerfield quadrangle, Guernsey, Noble, and Monroe counties, Ohio: U. S. Geol. Survey Bul l.621, p 1.22, 1915.

County (pp. 59–65). Samples for analysis were taken in the mines, and the results are given on page 38.

ANDERSON (BAKERSTOWN) COAL.

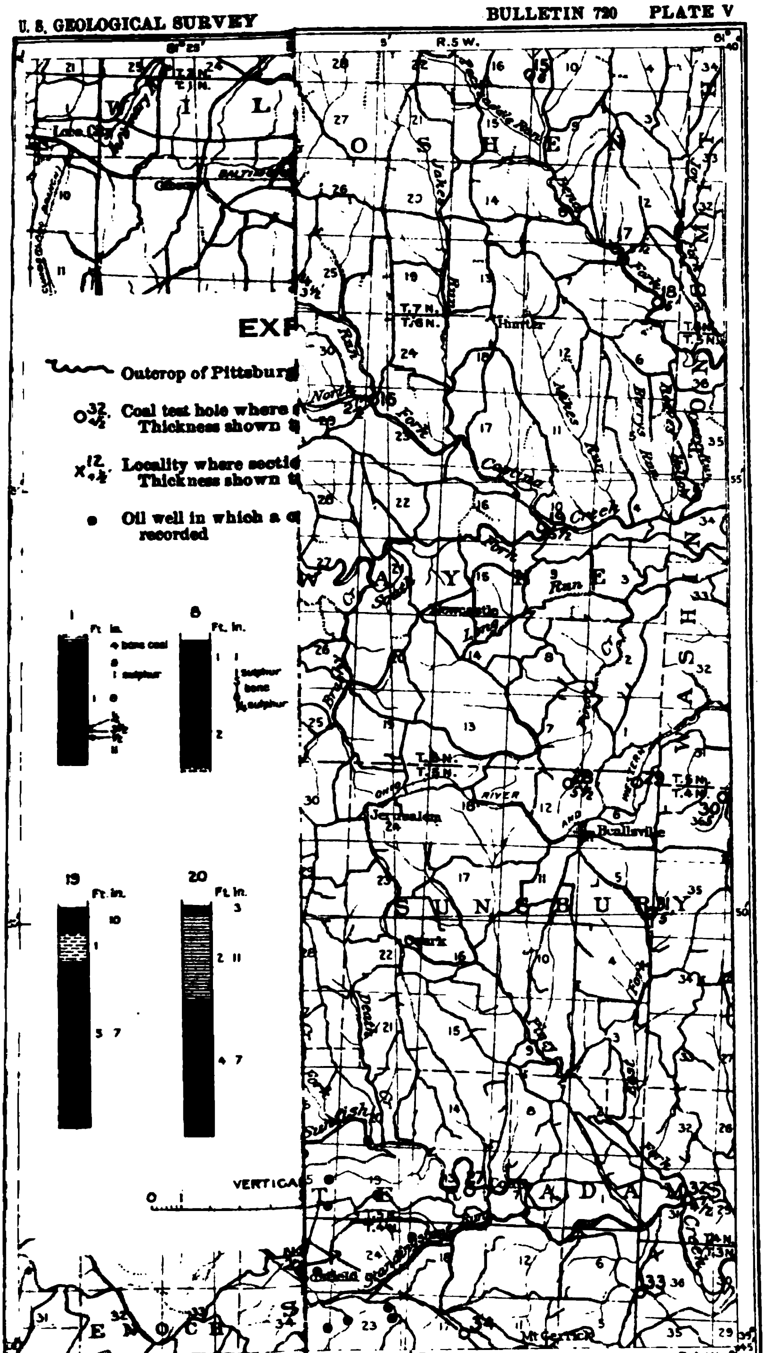
The Anderson coal bed is thin and of small extent. Its geologic position is about 10 feet above the Cambridge limestone. It is 1 to 2 feet thick in parts of Richland and Valley townships, Guernsey County, and has been used to a small extent by the farmers. The bed is probably at its best in the Andy Slovak mine, in sec. 11, Valley Township, where a thickness of 1 foot 10 inches was measured. A sample was cut for analysis and the result is given on page 39, No. 20243.

PITTSBURGH COAL.

The Pittsburgh coal bed will in the not distant future constitute the basis of a great mining industry. Practically all of the Woodsfield quadrangle except the southwest quarter is underlain by the coal in thicknesses of 4 to 5 feet, as yet almost untouched. Two commercial mines are in operation on the outcrop near Barnesville, and these are the only places where the coal has been mined in a large way in the southwestern part of Belmont County or the adjacent part of Monroe County. The bed in its extension eastward from Barnesville and Woodsfield to Ohio River, a distance of 25 miles, and beyond into West Virginia constitutes one of the greatest fuel reserves in the northern Appalachian region. (See fig. 5.)

There has been keen competition among lessees of coal tracts during the last 15 years, and nearly all the coal land is now under the control of coal companies. The prices paid have varied greatly, being only a few dollars an acre at the start but increasing to $25 or even as much as $40 an acre when the farmers had begun to realize the value of the coal.

Diamond-drill tests have, with the few exceptions noted elsewhere in this report, demonstrated the regularity in thickness of the Pittsburgh bed in Warren, Goshen, Somerset, Wayne, Smith, and Washington townships, Belmont County, and in Sunsbury, Adams, and parts of Malaga and Center townships, to the west, in Monroe County. Somewhere under cover in the southwestern part of the Woodsfield quadrangle the bed abruptly thins, and it is of no value farther southwest for many miles. At Temperanceville and northwestward toward Quaker City the line limiting the minable coal can readily be drawn, as represented on the maps (Pls. V and XII). For the area to the south, where the coal lies under cover, the line is drawn with less certainty from information derived from a few core-drill records and from oil-well records.



Base from U. S. Geological Survey maps
and Woodsfield quadrangles.

URGH

The doubtful character of the coal in the west half of Malaga Township, much of Center Township, and all of Summit Township is such that anyone considering the purchase of coal land in this area should insist on thorough prospecting with the diamond drill. Oil-well records, no matter how many, can not serve the same purpose, and the fact that the drillers report "Pittsburgh No. 8" coal as far west as Lewisville should be given little weight. There is always a possibility that the coal so reported may consist mostly of bone and shale or that it is not the Pittsburgh bed but rather another thin bed about 30 feet higher, variously known as the Pittsburgh Rider, Red-

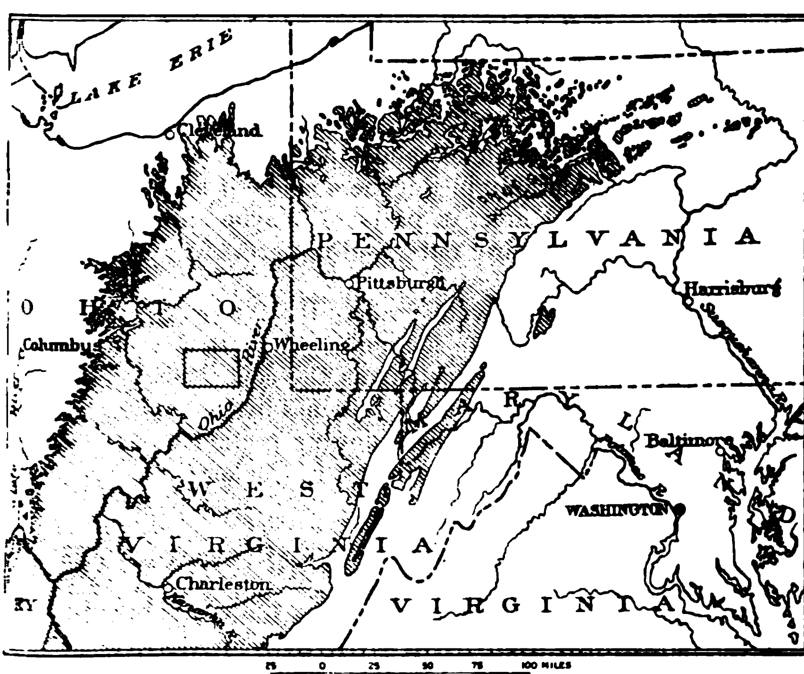


FIGURE 5.—Map of northern part of Appalachian coal field. The location of the Summerfield and Woodsfield quadrangles is shown by the rectangle in eastern Ohio opposite Wheeling, W. Va.

stone, or Pomeroy. Already a number of purchasers have acquired "gold bricks." Some of these transactions have involved lands whose worthlessness for coal is evident from direct field observations of the outcrop alone, and the purchasers could have been spared this mistake through the services of a geologist. Such lands are found in secs. 25, 26, 31, and 32 and part of sec. 33, in the northwest corner of Somerset Township, Belmont County, and in the western part of Malaga Township and possibly all of Summit Township, Monroe County. The disappearance of the coal along the valley west from Temperanceville has long been known. To the south along Rock Creek and its two forks the bed where geologically due

is marked by black shale resting on limestone. About 70 feet highe in the same valley is the Lower Meigs Creek coal, 2 to 3 feet thick which has been mistaken for the Pittsburgh by some geologists The same conditions prevail along the outcrop to the south acros the county line, in the valleys of Seneca and Paynes forks of Will Creek.

The township descriptions given in another part of this report se forth fully the evidence as to the thickness and character of th Pittsburgh coal in each township. A number of the measurement are also diagramatically represented on the index map (Pl. V). Th coal consists of one principal bed divided into several parts by thi layers of shale or "sulphur," some of which are fairly constant whereas others are of local extent. Above the principal bench ther may be a foot or so of clay overlain by several inches of impure coa commonly known as the roof coal. Elsewhere the roof coal may b missing or replaced by shale or sandstone. As a rule the coal bed i found to vary considerably in thickness where it is directly overlai by sandstone—for example, in parts of Wayne and Goshen town ships, as shown by core-drill data, and in parts of the Cochran min at Baileys Mills.

In southwestern Pennsylvania, where the Pittsburgh coal is at it best, the bed is divided into a number of parts by thin layers o shale that are almost as persistent as the coal itself. The severa parts of the coal bed have been given names by the miners, and som of them are recognizable in the following section measured in th Samuel Sayre mine, 1½ miles northwest of Quaker City.

Section of coal bed in Sayre mine.

	Ft.	in.
Shale, unmeasured:		
Bony coal		4
"Breast" coal:		
Coal		9
"Sulphur"		1
Coal	1	8
Shale		½
"Bearing in" coal		3½
Shale		½
"Bottom" coal		11

The heating value and chemical composition of the Pittsburgh co are shown by analyses of four samples, Nos. 20187, 20188, 20230, an 20178 in the table on page 39. The table also includes for compari son the analysis of a sample from the Connellsville coke region c southwestern Pennsylvania.[10] Evidently the Pittsburgh coal c Belmont County ranks considerably higher in heating value than th

[10] Analyses of coals in the United States, with descriptions of mine and fuel samples collected July 1904, to June 30, 1910: U. S. Bur. Mines Bull. 22, p. 168 (laboratory No. 4411).

Meigs Creek and other coals in the area, but it does not compare so favorably with the Pittsburgh of southwestern Pennsylvania.

LOWER MEIGS CREEK COAL.

The stratigraphic position of the Lower Meigs Creek coal bed, as shown by measurements recorded in the descriptions of townships, is 18 to 35 feet below the Meigs Creek coal. The two beds appear in outcrop in all parts of the Summerfield quadrangle and have been recorded in diamond-drill test holes and in oil wells to the east. In most places the Lower Meigs Creek coal is so insignificant that it has been overlooked or incorrectly identified, even by geologists. Its thickness at best is rarely found to be as much as 3 feet, and it includes numerous shaly, earthy bands and "sulphur." Both on the outcrop and to the east, where it lies far below the surface, this bed is locally 2 to 3 feet thick and with such dimensions extends throughout areas where the Meigs Creek coal is thin or lacking. In such places the Lower Meigs Creek may be mistaken for the Meigs Creek coal.

One of the most promising areas of this coal is in the valleys of westward-flowing tributaries of Wills Creek between Temperanceville and Monroefield. Here the coal lies under a massive sandstone and rests on gray limestone. At a few places the Meigs Creek coal appears about 30 feet higher. The Pittsburgh coal is of no value on the outcrop in this vicinity, although not so reported by some observers who have mistaken the Lower Meigs Creek coal for the Pittsburgh bed.

This coal is also 2 feet or more thick at certain places near Barnesville and northwest of Temperanceville, toward Quaker City. Detailed information concerning the bed in each township is given in the township descriptions.

No recent openings in the Lower Meigs Creek coal were discovered, and therefore no samples were taken for analysis. From numerous measurements and notes given in the township descriptions it is evident that the value of the coal is diminished by the presence of "sulphur" bands and numerous thin shaly partings. In its extent as a minable bed and in quality it can in no way compare favorably with the Meigs Creek coal.

MEIGS CREEK COAL.

The Meigs Creek coal ranks next to the Pittsburgh in value in the Woodsfield and Summerfield quadrangles. Along the outcrop it is best in the ridges westward from Summerfield to Sarahsville and southward for many miles beyond the limits of the area described in this report. From Summerfield northeastward to a point within a few miles of Barnesville is a barren area where the coal is thin or

lacking, but west of this area, in the high ridges, there is a narrow productive belt extending from Mount Ephraim through Batesville and Baileys Mills along the west side of Barnesville.

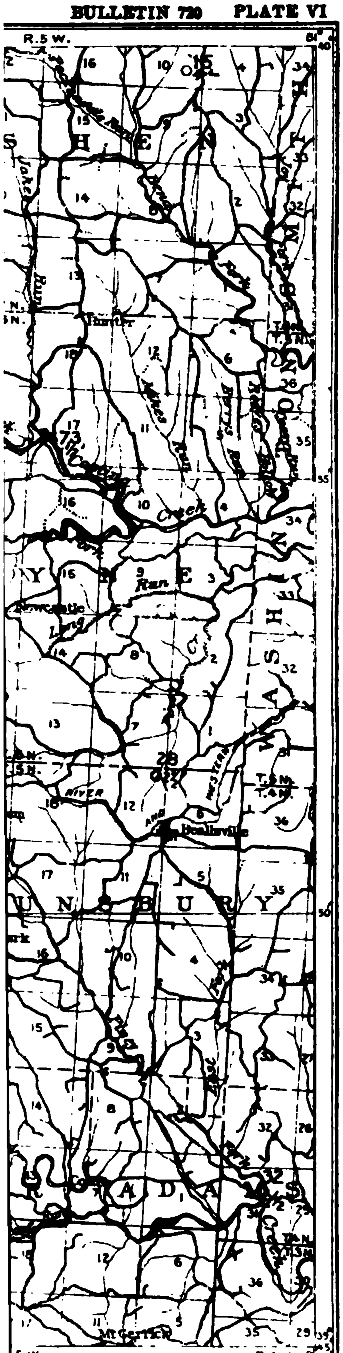
East of Barnesville the coal appears in outcrop low in the valley of Long Run and other tributaries of Captina Creek. Its southeastward dip is at about the same rate as the gradient of the streams, and therefore the coal lies 10 to 40 feet above the creek bed for miles and has been mined in a small way at dozens of places. Near the junction of North and South forks of Captina Creek the bed dips below the valley and is 10 to 20 feet under cover eastward for about 3 miles. According to report the coal has been stripped during low water near the mouth of Piney Creek. About 2 miles farther east, at Alledonia, it is at least 20 feet below the creek bed, but it rises again to the surface about 1 mile north of Alledonia, along and near the mouth of Bend Fork, where the coal has been mined for many years.

Careful search along Sunfish Creek in the southeastern part of the Woodsfield quadrangle failed to reveal an outcrop of the Meigs Creek coal, although its position for several miles should be near the valley floor or only slightly below, as indicated by the position of the Uniontown coal in the hills that border the valley.

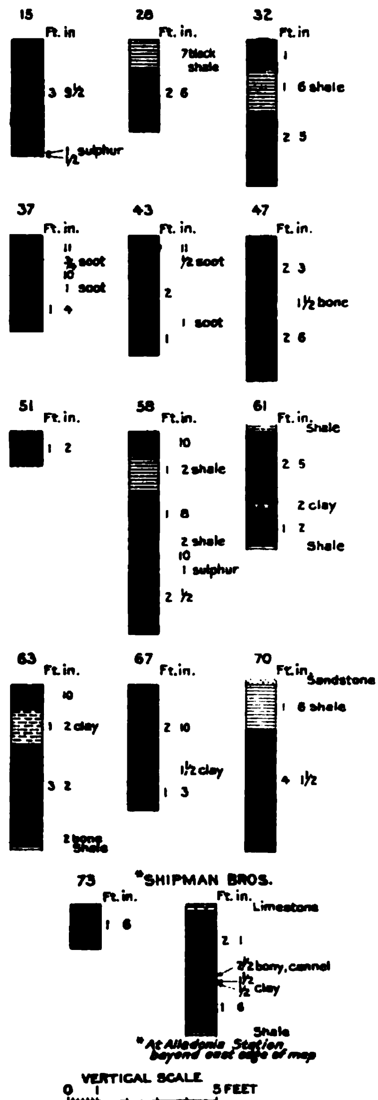
The extent of the Meigs Creek coal as a valuable bed under cover in the Woodsfield quadrangle is probably considerable. A careful inspection of the outcrop along Captina Creek shows the bed to be 3 to 4 feet thick at numerous places. It is subject to abrupt variations in thickness and quality along its outcrop, however, and therefore should be carefully prospected by the person who is considering the carrying on of mining operations on a large scale. In structure or the number of partings and shale bands it also shows considerable variation. The bed is evidently in no way comparable to the Pittsburgh coal as to persistence and general reliability.

Detailed information as to the bed on its outcrop in each township is set forth in another part of this report. The variation in thickness is shown roughly by Plate VI and the accompanying sections.

Among oil men the Meigs Creek coal is commonly known as the Mapletown and is so recorded in wells drilled for oil in all parts of the Woodsfield quadrangle. To the west, in the vicinity of Summerfield, it has been mistaken for the Pittsburgh coal by some people. The reliability of the reports of drillers as to the thickness of the Meigs Creek is of course subject to question, for the usual reasons, and also because another coal bed, the Lower Meigs Creek, lies 18 to 35 feet lower and is locally 2 to 3 feet thick where the Meigs Creek is thin or lacking, as on the outcrop south of Temperanceville, in valleys tributary to Seneca Fork, and also in several oil fields to the east where the coals have been recorded.



A. HOEN & CO. BALTIMORE



EXPLANATION

Outcrop of Meigs Creek coal where 1 foot or more thick

$\overset{32}{O_{2\frac{1}{2}}}$ Coal test hole where section was measured. Thickness shown to nearest half foot

$\overset{40}{X_{4'}}$ Locality where section was measured. Thickness shown to nearest half foot

Samples of the Meigs Creek coal were cut in five mines at widely separated localities. Sections of the coal bed at each locality are given on the index map (Pl. VI). Sections of the beds are also given on pages 45–46, and the calorific values and analyses of the samples on page 40.

UNIONTOWN COAL.

The extent of the Uniontown coal bed in workable thickness along its outcrop is less than that of the Waynesburg, about 60 feet higher, or the Meigs Creek, about 110 feet lower. Although geologically due in nearly all parts of the Woodsfield quadrangle and in much of the Summerfield quadrangle, it is of no economic importance, except along Sunfish Creek eastward from Woodsfield and along Captina Creek and its tributaries Jakes Run, Bend Fork, and Joy Run, in the northeast corner of the area. The coal is soft and earthy and is characterized by shale bands, which vary in thickness and number from place to place and are locally so numerous that they can not be separated from the coal by the miner. The character of the coal is illustrated by sections that accompany the index map (Pl. VII). On this map the extent of the coal where it is 1 foot or more in thickness is represented.

Along the ridge roads in the vicinity of Summerfield the Uniontown coal forms conspicuous "blossoms" that would indicate a good thickness. Where seen in clean exposures in the railroad cuts, however, it is found to consist largely of worthless bone interbedded with coal.

At Barnesville, Temperanceville, and Lewisville there is commonly a few inches of coal at the Uniontown horizon, together with more or less bony coal. Locally there are two thin layers of coal separated by 6 to 10 feet of shale.

The quality of the coal has been determined from samples taken at two localities. The results of the analyses are given in the table on page 40. The calorific value of the two samples as received is 11.660 and 11,540 British thermal units, and the ash content is 15.3 per cent in each sample. The heating value is similar to that of the Waynesburg coal, but considerably less than that of the Pittsburgh.

It is evident that the Uniontown coal will find its chief use as a convenient source of fuel for the farmers. The presence of numerous shale bands and a high ash content will be a serious drawback to its being mined for the market, even where the thickness is as much as 3 feet.

WAYNESBURG COAL.

The Waynesburg coal lies 265 to 285 feet above the Pittsburgh coal as found in the north half of the Woodsfield quadrangle. In that area it has long been mined, especially in the vicinity of Boston,

Somerton, Newcastle, and Hunter, and is designated the Four Foot Hard coal by the farmers. The bed is 2 to 3 feet think throughout nearly all of Somerset Township and 3 feet or more in parts of Goshen and Wayne townships, Belmont County. No exposures as thick as 1 foot were found to the south in Monroe County. The outcrop of the bed where 1 foot or more in thickness is represented on the index map (Pl. VIII).

The coal has been mined in a small way by the farmers for many years. The usual procedure is to drive a drift into the hillside from which the supply necessary for home use is taken out for a few seasons until the roof falls. Then another drift is made, and in this manner the hills have become scarred with numerous prospect holes. Many measurements in natural exposures and small mines were made in each township, and these are given in the township descriptions. Representative sections of the bed are given on Plate VIII.

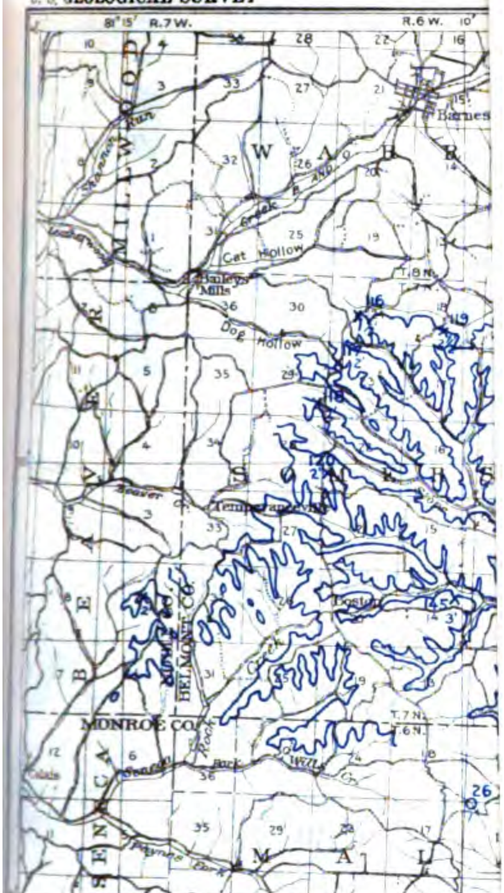
The Waynesburg coal was sampled at four localities, and the results are given in the table on page 41. The coal is high in ash, averaging about 15.2 per cent in the coal as it comes from the mine, but not nearly so high as the Washington coal, which shows 21 per cent. In heating value the coal averages about 11.730 British thermal units, a little more than the Washington coal but considerably less than the Pittsburgh coal.

The Waynesburg coal, as is evident from the sections, varies considerably in thickness from place to place and has no characteristic partings that are persistent throughout wide areas. Numerous sections and local details concerning the coal are given in the township descriptions.

WASHINGTON COAL.

The Washington is the highest coal bed in the geologic column of the area under consideration. There is, it is true, more or less impure bony coal about 140 feet higher at a few localities, but nowhere is it worthy of special attention as coal. The Washington bed almost everywhere on its outcrop consists of a layer 1 to 8 feet thick. It occurs, as shown by the maps (Pls. IX and XII), well up in the hills in the vicinity of Woodsfield, and gradually rises northward to the tops of the highest hills a little beyond the Belmont County line.

There are locally other coal beds 10 feet and 26 feet above the Washington coal, and where these are of any prominence they may be mistaken for the Washington. These "rider" coals were seen in the eastern part of Goshen Township and also in Malaga Township. Their thickness is nowhere as great as that of the Washington coal, and the beds will not be confused except where the exposures are poor.



EXPLANATION

Outcrop of Waynesburg coal where 1 foot or more thick

26 / 1' Coal test hole where section was measured. Thickness shown to nearest half foot

144 / 1½' Locality where section was measured. Thickness shown to nearest half foot

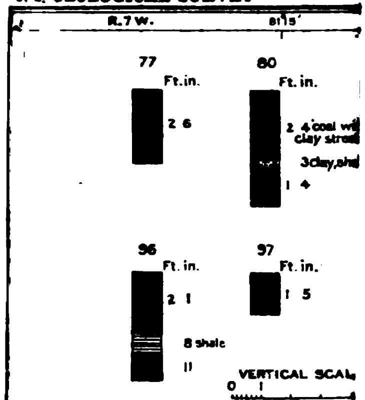
81°15' R.6 W. 10'

...s from U. S. Geological Survey maps of Summerfield and Woodsfield quadrangles.

INDEX MAP AND SECTIONS S...

WAYNESBURG COAL BED IN SUMM...

1 0

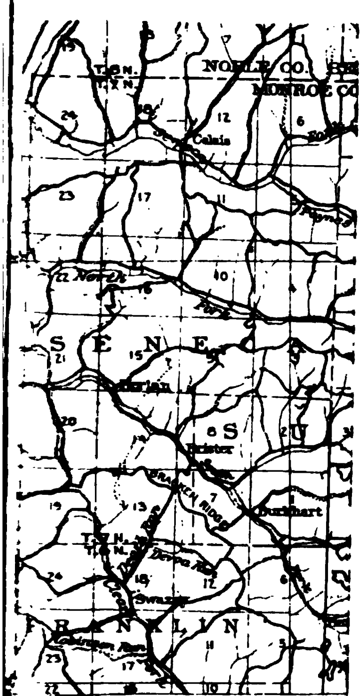


EXPLANATION

Outcrop of Washington coal
1 foot or more thick

18
3'
Coal test hole where sectio
measured. Thickness sh
nearest half foot

95
4'
Locality where section was
ured. Thickness shown t
est half foot



Base from U. S. Geological Survey maps of Summ
and Woodsfield quadrangles.

INDEX MAP AND

COAL BE

The thickness and structure of the Washington coal is shown by numerous measurements given in the township descriptions, a few of which are repeated on Plate IX for the convenience of the reader. The bed where thickest, as seen in Sunbury Township and to the north near Captina Creek, consists of two layers each 1 to 2 feet thick, separated by a foot or so of clay shale. It shows a similar make-up also in other localities to the west.

This coal has been mined entirely by the farmers for their own use, and the method followed has, except at a few small drift mines, been stripping along the outcrop in ravines. The thinness, the shaly partings, and the extremely high ash content (21 per cent) are unfavorable features of the coal. Throughout most of the area there are other more accessible coal beds to supply the local demand, and much coal from commercial mines is also distributed to the villages on the railroads. Therefore the prospective value of the Washington coal is slight.

A sample was taken in the S. A. Moore mine, sec. 33, Washington Township, one of the few places where the coal has been extracted by drift mining. The section of the bed is given on Plate IX, and the analysis of the sample on page 41.

The measurements given on the index map are selected as representative of the coal in the areas mentioned. The bed is evidently at its best at the east side of the Woodsfield quadrangle, where it comprises an upper and a lower bench. In the section measured at Hunter there is a suggestion of the two benches, but the upper bench of coal is decidedly shaly. In the vicinity of Woodsfield and to the east and west for several miles the coal consists of a single layer 14 to 17 inches thick. Before the construction of the railroad and the shipping of fuel from more distant sources, this coal, being almost the only bed of any value in the area, was extensively stripped. The coal as found in the high hills along the county line north of Malaga commonly shows the two benches represented in the section at locality 87. (See Pl. IX.) Roadside and ravine exposures are plentiful, but few of the farmers have found it necessary to use this coal, because they can obtain a more convenient supply from the Waynesburg bed, which has a fair development in the same vicinity.

COMPOSITION OF THE COAL.

COAL SAMPLING.

The method of sampling of coal beds as described by Campbell [11] were followed in the collection of the samples. All samples are collected in mines or prospects at the freshest place available. The

[11] Miscellaneous analyses of coal samples from various fields of the United States: U. S. Geol. Survey Bull. 531, pp. 331–333, 1913.

collector faces up the bed until fresh material is bared and then obtains his sample by making a uniform cut across the bed from roof to floor, including all such benches and partings as an experienced and careful miner would include in commercial coal and throwing out such impurities as would certainly be excluded in practical operation. He cuts sufficient coal to give at least 6 pounds for each foot of coal bed sampled. The sample is pulverized in the mine until it will pass through a ½-inch mesh and then is quartered down until about 4 pounds remains. This is placed in a galvanized-iron can, sealed with adhesive tape or paraffin, and mailed to the laboratory for analysis. The sampling is done on the principle that a coal mine should be sampled as carefully as a gold mine and that the sample should be even more carefully handled after it has been taken. The object of sealing is to prevent change in the moisture content, so that the coal may reach the laboratory in practically the same condition that it exists in the mine. Coal is a very unstable substance, and great care must be exercised to prevent oxidation in the course of preparation and in transit. It is also important that the sample should consist of neither the best nor the poorest coal, but that it should be representative of the output of the mine, if one is in operation, or, if the field is undeveloped, it should represent as nearly as possible the merchantable coal that may be obtained at some time in the future when mining is carried on.

Although the aim of the geologist in obtaining a sample by the method specified above is to obtain coal that is representative of the output of the mine, practical experience has shown that this is seldom or never accomplished. Almost invariably the sample obtained in the mine contains a lower percentage of impurities than the coal which reaches the consumer. This is due largely to carelessness in mining and handling and probably could be largely eliminated were the conditions of mining more nearly ideal.

ANALYSES.

All the analytical work was done by chemists of the Bureau of Mines. In the table the analyses are given in three forms, marked "A," "B," and "C." Analysis A represents the sample as it comes from the mine. Analysis B represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis C represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms B and C are obtained from the other merely by recalculation. They should not be used except in theoretical comparisons, for they represent theoretical substances that do not exist.

The coal of this part of Ohio will sooner or later come into direct competition with coal from adjacent States, so it is best for all concerned—the operator as well as the consumer—to understand fully their comparative values. The demand for fuel in this area is perhaps not now sufficient to attract coal from Pennsylvania and West Virginia, but it eventually will be; and as soon as the local coal is shipped out of the area it will come into direct competition with better coal from the areas farther east and south.

The coal of the Summerfield and Woodsfield quadrangles may be able to hold its own indefinitely in the local market, where the demands are not so exacting as they are elsewhere, and the low freight rates on it as compared with those on coal shipped from Pennsylvania and West Virginia may make it really cheaper. But for producing steam, especially in big power or manufacturing plants, it will come into direct competition with better coal, and the tendency now is to select coal for such plants only after a long series of tests has been made to show exactly the comparative values of a number of available coals.

The coal of the Summerfield and Woodsfield quadrangles has four characteristics which should be carefully considered—high moisture, high ash, high sulphur, and low heating value. The low heating value is of course but the logical result of the high percentages of moisture and ash, for as these impurities increase the heating value of the coal diminishes. Another fact to be noted is the general decrease in the efficiency of the coal in the Appalachian trough from its east to its west side, due to the decrease in the effect of metamorphism in that direction, which is shown by the change in the comparative heating value of the Pittsburgh coal from Lore City, in this area, eastward to Frostburg, in Maryland. Thus the heating value of the Pittsburgh coal mined near Barnesville, in British thermal units, is 12,840; near Wheeling W. Va., it is 13,000; at Pittsburgh, Pa., 13,400; at Connellsville, Pa., 13,600; and at Frostburg, Md., 14,000. The best coals of Pennsylvania and West Virginia yield about 14,000 British thermal units and contain not much more than 1 per cent of sulphur and about 6 or 7 per cent of ash.

The exact quantity of sulphur in coal to be used for raising steam or for heating is not of great significance, but tbe quantity in coal to be used for making coke for smelting iron is of paramount importance. Most of the coals in this field contain too large a percentage of sulphur to be used for making coke, except perhaps the Upper Freeport coal which averages about 1½ per cent. The same is true of coal to be used for the manufacture of gas, so that these coals are unadapted to such uses until some inexpensive process of reducing materially their content of sulphur is devised.

Analyses of coal samples from the Summerfield and Woodsfield quardangles, Ohio.

[Made by the Bureau of Mines.]

Upper Freeport coal bed.

	Location.			Laboratory No.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
	Sec.	T.	R.			Moisture.	Volatile matter.	Fixed Carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Blacktop mine, Morris Coal Co., 1 mile west of Lore City, Guernsey County.	8	1 N.	2 W.	20264	A.	6.1	35.2	51.8	6.9	1.62					7,075	12,740
					B.		37.5	55.1	7.4	1.72					7,535	13,570
					C.		40.5	59.5		1.86					8,135	14,650
Do	8	1 N.	W.	20265	A.	6.0	35.7	50.4	7.9	2.15					7,035	12,660
					B.		38.0	53.6	8.4	2.29					7,480	13,460
					C.		41.5	58.5		2.50					8,170	14,700
Composite sample, mixture of Nos. 20264 and 20265	8	1 N.		20266	A.	6.1	35.0	51.6	7.33	1.95	5.37	71.24	1.39	12.72	7,060	12,710
					B.		37.3	54.9	7.80	2.08	5.00	75.84	1.48	7.80	7,520	13,530
					C.		40.5	59.5		2.26	5.42	82.26	1.61	8.45	8,155	14,680
Cleveland mine, Morris Coal Co., Senecaville, Guernsey County.	21	1 N.	2 W.	20261	A.	5.4	35.8	50.8	8.0	1.64					7,100	12,780
					B.		37.8	53.7	8.5	1.73					7,505	13,510
					C.		41.4	58.6		1.89					8,205	14,770
Do	21	1 N.	2 W.	20262	A.	6.4	33.7	52.1	7.8	2.16					7,015	12,630
					B.		36.0	55.7	8.3	2.30					7,495	13,490
					C.		39.2	60.8		2.51					8,175	14,720
Composite sample, mixture of Nos. 20261 and 20262	21	1 N.	2 W.	20263	A.	6.0	34.2	52.0	7.83	1.98	5.38	71.38	1.32	12.11	7,065	12,720
					B.		36.4	55.3	8.33	2.11	5.01	75.93	1.40	7.22	7,520	13,530
					C.		39.7	60.3		2.30	5.47	82.83	1.53	7.87	8,200	14,760
Walhonding mine No. 2, 1 mile east of Hartford, Guernsey County.	11	8 N.	9 W.	20245	A.	6.9	34.1	53.3	5.7	.84					7,105	12,790
					B.		36.6	57.2	6.2	.90					7,630	13,730
					C.		39.0	61.0		.96					8,130	14,640
Do	11	8 N.	9 W.	20246	A.	6.2	36.2	52.3	5.3	.88					7,225	13,000
					B.		38.6	55.8	5.6	.94					7,705	13,870
					C.		40.9	59.1		1.00					8,170	14,700
Composite sample, mixture of Nos. 20245 and 20246	11	8 N.	9 W.	20247	A.	6.5	35.4	52.6	5.53	.88	5.49	73.42	1.37	13.31	7,190	12,940
					B.		37.9	56.2	5.91	.94	5.10	78.51	1.46	8.08	7,690	13,840
					C.		40.3	59.7		1.00	5.42	83.44	1.55	8.59	8,170	14,710

Anderson coal bed.

Prospect of Andy Slovak, 1 mile east of Hartford, Guernsey County.	11	8 N.	9 W.	20243	A.	4.3	40.2	45.1	10.39	3.75	5.37	68.30	1.50	10.69	6,940	12,490
					B.	....	42.0	47.1	10.86	3.92	5.11	71.39	1.57	7.15	7,255	13,060
					C.	....	47.2	52.8	....	4.40	5.73	80.09	1.76	8.02	8,140	14,650

Pittsburgh coal bed.

Small mine of Samuel Sayre, 1½ miles northwest of Quaker City, Guernsey County.	21	9 N.	7 W.	20178	A.	4.4	41.1	45.8	8.74	4.85	5.37	69.30	1.26	10.48	7,000	12,710
					B.	....	43.0	47.9	9.14	5.07	5.11	72.46	1.32	6.90	7,385	13,290
					C.	....	47.4	52.6	....	5.58	5.62	79.75	1.45	7.60	8,125	14,630
Cochran mine No. 2, Bixler Ohio Coal Co., Baileys Mills, 3½ miles southeast of Barnesville, Belmont County.	31	8 N.	6 W.	20187	A.	4.1	42.7	43.9	9.3	4.46	....	....	....	....	7,075	12,730
					B.	....	44.6	45.7	9.7	4.65	....	....	....	....	7,380	13,280
					C.	....	49.4	50.6	....	5.15	....	....	....	....	8,175	14,710
Do.	31	8 N.	6 W.	20188	A.	3.7	43.3	44.4	8.6	4.45	....	....	....	....	7,195	12,950
					B.	....	44.9	46.1	9.0	4.62	....	....	....	....	7,470	13,450
					C.	....	49.3	50.7	....	5.07	....	....	....	....	8,205	14,770
Composite sample, mixture of Nos. 20187 and 20188.	31	8 N.	6 W.	20189	A.	3.9	43.1	43.9	9.07	4.36	5.46	69.97	1.27	9.87	7,130	12,840
					B.	....	44.8	45.8	9.44	4.54	5.23	72.80	1.32	6.67	7,420	13,360
					C.	....	49.5	50.5	....	5.01	5.77	80.39	1.46	7.37	8,195	14,750
Jefferies mine, Temperanceville, Belmont County.	33	7 N.	6 W.	20230	A.	3.7	41.0	45.8	9.5	4.57	....	....	....	....	7,090	12,760
					B.	....	42.6	47.5	9.9	4.75	....	....	....	....	7,365	13,250
					C.	....	47.3	52.7	....	5.27	....	....	....	....	8,170	14,700

Analyses of coal samples from the Summerfield and Woodsfield quadrangles, Ohio—Continued.

[Made by the Bureau of Mines.]

Meigs Creek coal bed.

	Location.			Laboratory No.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
	Sec.	T.	R.			Moisture.	Volatile matter.	Fixed Carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Small mine of Wiley Carter, 1 mile north of Mount Ephraim Station, Noble County.	33	8 N.	8 W.	20235	A.	4.5	39.6	45.6	10.32	4.12	5.27	68.00	1.17	11.12	6,815	12,320
					B.	....	41.4	47.8	10.81	4.32	5.00	71.22	1.23	7.42	7,170	12,910
					C.	....	46.5	53.5	....	4.84	5.61	79.85	1.38	8.32	8,040	14,470
Small mine of J. T. Moore, 1 mile west of Steamtown, Noble County.	11	7 N.	8 W.	20240	A.	3.6	41.5	44.4	10.53	4.87	5.25	68.15	1.11	10.09	6,945	12,510
					B.	....	43.1	46.0	10.92	5.05	5.03	70.67	1.15	7.18	7,205	12,970
					C.	....	48.4	51.6	....	5.67	5.65	79.33	1.29	8.05	8,085	14,560
Small mine of G. W. Griffin, 3 miles southeast of Quaker City, Noble County.	11	8 N.	7 W.	20185	A.	4.2	38.4	44.8	12.62	3.61	5.22	66.87	1.20	10.48	6,740	12,130
					B.	....	40.1	46.7	13.17	3.77	4.97	69.76	1.25	7.08	7,030	12,650
					C.	....	46.2	53.8	....	4.31	5.72	80.34	1.44	8.16	8,095	14,570
Small mine of Thomas Davy, 1 mile southwest of Barnesville, Belmont County.	20	8 N.	6 W.	20176	A.	4.3	39.0	45.5	11.21	3.65	5.31	68.17	1.20	10.46	6,890	12,400
					B.	....	40.7	47.6	11.72	3.81	5.05	71.26	1.25	6.91	7,205	12,970
					C.	....	46.1	53.9	....	4.32	5.72	80.72	1.42	7.82	8,160	14,690
Surface prospect of Shipman Bros., 1 mile north of Alledonia, Belmont County, 2 miles east of this area.	22	5 N.	4 W.	20237	A.	3.5	37.2	41.5	17.8	4.05	....	....	....	....	6,395	11,510
					B.	....	38.5	43.0	18.5	4.20	....	....	....	....	6,630	11,930
					C.	....	47.2	52.8	....	5.15	....	....	....	....	8,130	14,630

Uniontown coal bed.

	Sec.	T.	R.	Laboratory No.	Form of analysis.	Moisture.	Volatile matter.	Fixed Carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Prospect of Peter Kamp, 2 miles east of Hunter, Belmont County. Coal weathered.	1	7 N.	5 W.	20775	A.	4.7	34.2	45.8	15.34	2.85	4.95	63.71	1.33	11.82	6,480	11,660
					B.	....	35.9	48.0	16.10	2.99	4.65	66.85	1.40	8.01	6,800	12,240
					C.	....	42.8	57.2	....	3.56	5.54	79.68	1.67	9.55	8,105	14,590
Prospect of Charles Mobley, 5 miles east of Woodsfield, Monroe County. Coal weathe ed.	31	4 N.	4 W.	20259	A.	4.9	35.9	43.9	15.32	3.96	4.87	63.59	1.19	11.07	6,410	11,540
					B.	....	37.8	46.1	16.10	4.16	4.55	66.83	1.2[illegible]	7.11	6,740	12,130
					C.	....	45.0	55.0	....	4.96	5.42	79.65	1.49	8.48	8,030	14,460

Waynesburg coal bed.																
Small mine of George Thomas, 1½ miles east of Boston, Belmont County.	14	7 N.	6 E.	20241	A.	4.5	36.6	44.2	14.75	3.02	5.10	65.32	1.16	10.65	6,555	11,800
					B.		38.3	46.3	15.44	3.16	4.81	68.37	1.21	7.01	6,860	12,350
					C.		45.3	54.7		3.74	5.69	80.85	1.43	8.29	8,110	14,600
Small mine of Howard Brown, 2 miles southeast of Somerton, Belmont County.	26	6 N.	5 W.	20234	A.	4.4	37.1	43.1	15.4	2.90					6,475	11,660
					B.		38.8	45.0	16.2	3.03					6,775	12,190
					C.		46.3	53.7		3.61					8,080	14,540
Prospect of J. D. Milhoan, 1½ miles northeast of Hunter, Belmont County.	7	7 N.	5 W.	20174	A.	4.3	35.3	44.2	16.22	3.53	4.98	64.10	1.20	9.97	6,445	11,610
					B.		36.9	46.1	16.95	3.69	4.70	66.98	1.25	6.43	6,735	12,130
					C.		44.4	55.6		4.44	5.66	80.65	1.50	7.75	8,110	14,600
Small mine of Nathan Davis, 1 mile southwest of Alledonia, Belmont County, 1 mile east of this area.	27	5 N.	4 W.	20236	A.	4.6	36.8	44.2	14.4	2.59					6,575	11,830
					B.		38.6	46.3	15.1	2.71					6,890	12,400
					C.		45.5	54.5		3.19					8,120	14,610
Washington coal bed.																
Prospect of S. A. More, 1½ mile southwest of Alledonia, Belmont County.	33	5 N.	4 W.	20238	A.	4.1	33.7	41.2	21.00	2.86	4.76	59.93	1.09	10.36	6,010	10,820
					B.		35.1	43.0	21.89	2.98	4.49	62.48	1.14	7.02	6,270	11,280
					C.		45.0	55.0		3.81	5.75	79.99	1.46	8.99	8,025	14,440

Average of analyses for each coal.

Coal bed.	Sulphur.	Ash.	British thermal units.	Moisture.
Upper Freeport (9 analyses)	1.57	7.0	12,770	6.2
Anderson (1 analysis)	3.75	10.4	12,400	4.3
Pittsburgh (5 analyses)	4.54	9.0	12,800	4.0
Meigs Creek (5 analyses)	4.06	12.5	12,170	4.0
Uniontown (2 analyses)	3.40	15.3	11,600	4.8
Waynesburg (4 analyses)	3.01	15.2	11,730	4.5
Washington (1 analysis)	2.86	21.0	10,820	4.1

MINES FROM WHICH SAMPLES WERE OBTAINED.

In the following descriptions, which are arranged in the same order as the table of analyses, the numbers in black-face type are the laboratory numbers of the samples.

UPPER FREEPORT COAL.

20264, 20265. Blacktop, a shaft mine of the Morris Coal Co. on a spur from the Baltimore & Ohio Railroad, 1 mile west of Lore City, sec. 8, T. 1 N., R. 2 W., Richland Township, Guernsey County. Upper Freeport coal at top of Allegheny formation; thickness variable. The bed was measured and sampled at two points by D. Dale Condit on November 28, 1914, as described below.

Sections of coal bed in Blacktop mine.

	20264	20265
	Ft. in.	*Ft. in.*
Roof, shale.		
Coal	2 6	2 3
Coal, bony	1¼	2¼
Coal	1 2¼	1 7
Bone	[a] 2	[a] 2¼
Coal	10	1 9
Floor, clay.		
Thickness of bed	4 10	6
Thickness of coal sampled	4 8	5 9¾

[a] Not included in sample.

20264. Entry 23 east off main south entry, 6,200 feet S. 15° E. of shaft. The mine was dry at the point of sampling.
20265. Near end of main south entry, 7,300 feet S. 12° W. of shaft.

The upper bony band in the coal was included in the samples. The lower bone band is excluded in mining. The shaft is about 102 feet deep. The average daily output in 1914 was reported to be 1,000 tons.

20261, 20262. Cleveland, a shaft mine of the Morris Coal Co. on a branch of the Baltimore & Ohio Railroad at Senecaville, sec. 21, T. 1. N., R. 2 W., Richland Township, Guernsey County. Upper Freeport coal; thickness variable. Sandstone roll encountered in workings. The bed was measured and sampled at two points by Frank Reeves on November 28, 1914, as described below.

Sections of coal bed in Cleveland mine.

	20261	20262
	Ft. in.	Ft. in.
Roof, shale or sandstone.		
Coal	1 6	8
"Soot"	¼	½
Coal	8	1 0
Bone	a 1	
Coal	7	
"Soot"	¼	½
Coal	4	7
"Soot"	¼	
Coal	8	
Bone	a 2	a ¼
Coal	9	6
"Soot"	a ½	¼
Coal	4	8
"Soot"	a ½	¼
Coal	9	6
Bone		a 2
Coal		4
Bone		a 1
Coal		7
Floor, clay.		
Thickness of bed	5 11¾	5 3¼
Thickness of coal sampled	5 7¾	4 11¾

a Not included in sample.

20261. Room No. 5 east, off main north entry, 5,000 feet east of shaft.
20262. 10,500 feet north of shaft.

20245, 20246. Waldhonding No. 2, a shaft mine of the Cambridge Colliery Co. on a spur of the Baltimore & Ohio Railroad, sec. 11, T. 8 N., R. 9 W., Valley Township, 1 mile east of Hartford. Upper Freeport coal; thickness variable. The bed was measured and sampled at two points by Frank Reeves on November 27, 1914, as described below.

Sections of coal bed in Waldhonding No. 2 mine.

	20245	20246
	Ft. in.	Ft. in.
Roof, shale.		
Coal	2	1 9
"Soot"	¼	a ½
Coal	8	1 6
"Soot"	a ½	¼
Coal	2 0	4
"Soot"	a ½	a ½
Coal	7	9
"Soot"	¼	
Coal	8	
Clay	a ¾	
Coal	6	
Bone	a 1½	a 1
Coal	1 2	10
Floor, clay.		
Thickness of bed	6 ¾	5 4¼
Thickness of coal sampled	5 9½	5 2¼

a Not included in sample.

20245. 600 feet southeast of shaft.
20246. 3,400 feet northwest of shaft.

ANDERSON COAL.

20243. Drift mine operated by Andy Slovak at Waldhonding, a mining village 1 mile east of Hartford, in sec. 11, T. 8 N., R. 9 W., Valley Township, Guernsey County, on branch of Baltimore & Ohio Railroad. Anderson (Bakerstown) coal; thickness averages about 1¾ feet. The coal is mined in a very small way for local use. The bed has a similar thickness throughout a considerable area but has been

mined at only a few places. The sample was cut by Frank Reeves on November 27, 1914, at a point 75 feet from the mine mouth, where the bed consists of 22 inches of coal with a sandstone roof and shale floor.

PITTSBURGH COAL.

20178. Drift mine operated by Samuel Sayre, locality 1, sec. 21, T. 9 N., R. 7 W., Millwood Township, 1½ miles northwest of Quaker City, Guernsey County. Pittsburgh coal; thickness averages about 4 feet. The two shale partings in the lower portion, so characteristic of the bed, are persistent in this region. The other divisions are less uniform. The sample was taken from a fairly dry room at a point 350 feet east of the mine mouth. The vertical cover is about 70 feet. This and other small mines in the neighborhood supply the country demand. The bed was sampled by D. Dale Condit on November 20, 1914, as described below.

Section of coal bed in Samuel Sayre's mine.

	20178	
Roof, clay shale.	*Ft.*	*In.*
Coal, bony		[a] 4
Coal		9
"Sulphur"		[a] 1
Coal	1	8
Shale		[a] ½
Coal		3⅜
Shale		[a] ⅜
Coal		11
Floor, clay.		
Thickness of bed	4	1¼
Thickness of coal sampled	3	7⅜

[a] Not included in sample.

20187, 20188. Cochran No. 2, a drift mine of the Bixler Ohio Coal Co., locality 8, sec. 31, T. 8 N., R. 6 W., Warren Township, Belmont County, on the Baltimore & Ohio Railroad at Baileys Mills, 3½ miles southwest of Barnesville. Pittsburgh coal; thickness about 4 feet. The bed dips eastward at an an angle of less than 1°. In the mine is a sandstone "roll" which reduces the thickness of the coal in certain entries. The output of the mine is shipped to Columbus and other points west. The coal was measured and sampled at two points by R. V. A. Mills on November 25, 1914, as described below.

Sections of coal bed in Cochran No. 2 mine.

	20187		20188	
Roof, clay or sandstone.	*Ft.*	*in.*	*Ft.*	*in*
Coal		9	1	1
"Sulphur"		[a] 1		[a] 1
Coal	2	11	....	
Coal, impure	....			5
Bone	....			1
Coal	....			6
"Sulphur"	....			¼
Coal	....		2	
Floor, clay.				
Thickness of bed	3	9	4	2¼
Thickness of coal sampled	3	8	4	1¼

[a] Not included in sample.

20187. Face of main north entry, 1 mile north of mine mouth.
20188. Room 6, off No. 15 west entry, three-fourths mile north of mine mouth.

20230. Jefferies wagon mine, Temperanceville, locality 12, sec. 33, T. 7 N., R. 6 W., Somerset Township, Belmont County, 4 miles south of the Baltimore & Ohio Railroad. Pittsburgh coal; thickness fairly uniform, about 3 feet 8 inches. The

thickness of the coal in this mine varies only slightly. In the same vicinity, however, the coal thins toward the south. It is of little if any importance in the hills south of Temperanceville. The bed was measured and sampled at a point 600 feet north of the mine mouth by R. V. A. Mills on November 22, 1914, as described below.

Section of coal bed in Jefferies mine.

	20230	
	Ft.	*in.*
Roof, clay.		
Coal		7½
"Soot" streak	[a]	½
Coal		4½
Bone	[a]	½
Coal	1	7
"Sulphur"	[a]	½
Coal	1	
Floor, clay.		
Thickness of bed	3	8½
Thickness of coal sampled	3	7

[a] Not included in sample.

MEIGS CREEK COAL.

20235. A small mine on the Wiley Carter farm, locality 37, sec. 33, T. 8 N., R. 8 W., Seneca Township, Noble County, 1 mile north of Mount Ephraim Station on Ohio River & Western Railroad. Meigs Creek (Sewickley) coal. The sample was cut in a fairly dry room 300 feet west of the mine mouth. The bed was measured and sampled by Frank Reeves on November 26, 1914, as described below.

Section of bed in Wiley Carter's mine.

	20235	
	Ft.	*in.*
Roof, shale.		
Coal		11
"Soot"	[a]	¾
Coal		10
"Soot"	[a]	1
Coal	1	4
Floor, shale.		
Thickness of bed	3	2¾
Thickness of coal sampled	3	1

[a] Not included in sample.

20240. A small mine on the J. T. Moore farm, locality 43, sec. 11, T. 7 N., R. 8 W., Marion Township, Noble County, 1 mile west of Steamtown, the nearest station on the Ohio River & Western Railroad. Meigs Creek (Sewickley) coal. The sample was cut at a point 480 feet south of the mine mouth, where the vertical cover is about 50 feet. The bed was measured and sampled by Frank Reeves on November 26, 1914, as described below.

Section of coal bed in J. T. Moore's mine.

	20240	
	Ft.	*in.*
Roof, shale.		
Coal		11
"Soot"	[a]	½
Coal	2	0
"Soot"	[a]	1
Coal	1	0
Floor, clay shale.		
Thickness of bed	4	½
Thickness of coal sampled	3	11

[a] Not included in sample.

20185. A small mine on the G. W. Griffin farm, locality 61, sec. 11, T. 8 N., R. 7 W., Beaver Township, Noble County, 3 miles southeast of Quaker City, the nearest village on the Baltimore & Ohio Railroad. Meigs Creek (Sewickley) coal. The roof of clay shale is not secure. The sample was cut at a point 350 feet west of the mine mouth, where the vertical cover is about 75 feet. The bed was measured and sampled by D. Dale Condit on November 22, 1914, as described below.

Section of coal bed in G. W. Griffin's mine.

	20185	
	Ft.	*in.*
Roof, clay shale.		
Coal	2	5
Clay	[a]	2
Coal	1	2
Floor, clay shale.		
Thickness of bed	3	9
Thickness of coal sampled	3	7

[a] Not included in sample.

20176. Thomas Davy's drift mine, locality 63, sec. 20, T. 8 N., R. 6 W., Warren Township, Belmont County, 1 mile southwest of Barnesville, near the Baltimore & Ohio Railroad. Meigs Creek (Sewickley) coal; thickness fairly uniform, about 3 feet 6 inches in this mine, not including the roof coal, which is not minable. The coal is mined at several places near Barnesville for the local market. The mine at the point of sampling was dry. The sample was cut at a point 350 feet southwest of the mine mouth. The bed was measured and sampled by D. Dale Condit on November 20, 1914, as described below.

Section of coal bed in Thomas Davy's mine.

	20176	
	Ft.	*in.*
Roof, clay.		
Coal, impure	[a]	10
Clay	[a]1	2
Coal	3	2
Bone	[a]	2
Floor, shale.		
Thickness of bed	5	4
Thickness of coal sampled	3	2

[a] Not included in sample.

20237. Shipman Bros.' small drift mine, on the bank of Captina Creek in sec. 22, T. 5 N., R. 4 W., Washington Township, Belmont County, 1 mile north of Alledonia, a station on the Ohio River & Western Railroad. Meigs Creek (Sewickley) coal; thickness 3½ to 4 feet. The roof is clay with irregular limestone layers. The mine has extended about 40 feet from the mouth, and the sample was taken at the face. The sample showed little evidence of weathering. The roof of clay and limestone is not secure and falls badly on weathering. The bed was measured and sampled by D. Dale Condit on November 26, 1914, as described below.

Section of coal bed in Shipman Bros.' mine.

	20237	
	Ft.	*in.*
Roof, clay and limestone.		
Coal	2	1
Coal, bony cannel		2½
Coal		1½
Clay		[a]½
Coal	1	6
Floor, clay shale.		
Thickness of bed	3	11½
Thickness of coal sampled	3	11

[a] *Not included in sample.*

UNIONTOWN COAL.

20775. Prospect on Peter Kemp farm, locality 103, sec. 1, T. 7 N., R. 5 W., Goshen Township, Belmont County, 2 miles east of Hunter and 5 miles southeast of Bethesda, the nearest town on the Baltimore & Ohio Railroad. Uniontown coal; thickness variable; one or more shale divisions that vary in thickness, and locally are more prominent than the coal. The roof ranges from sandy shale to sandstone. The floor is commonly clay shale. The sample was taken at a point 20 feet from the mine mouth. It was fairly dry and considerably weathered. The bed was measured and sampled by D. Dale Condit on November 21, 1914, as described below.

Section of coal bed in Peter Kemp's prospect.

	20775	
	Ft.	*in.*
Roof, sandy shale.		
Coal	2	6
Shale		[a] 1
Coal		3
Shale		[a] 5
Coal		7
Floor, clay shale.		
Thickness of bed	3	10
Thickness of coal sampled	3	4

[a] Not included in sample.

20259. A small mine on the Charles Mobley farm, locality 113, sec. 31, T. 4 N., R. 4 W., Adams Township, Monroe County, 2½ miles east of Coats Station, the nearest point on the Ohio River & Western Railroad. Uniontown coal. The following section shows the clay bands and bony streaks so prevalent in the Uniontown coal. The sample was weathered and stained with iron rust. The sample was cut at a point 40 feet from the mine mouth by D. Dale Condit on November 27, 1914, as described below.

Section of coal bed in Charles Mobley's mine.

	20259	
	Ft.	*in.*
Roof, shale.		
Coal, bony at top	1	7
Shale		[a] 3½
Coal		10½
Shale		[a] 2
Coal		6
Floor, clay shale.		
Thickness of bed	3	5
Thickness of coal sampled	2	11½

[a] Not included in sample.

WAYNESBURG COAL.

20241. George Thomas's drift mine, locality 145, sec. 14, T. 7 N., R. 6 W., Somerset Township, Belmont County, 2 miles east of Boston (Atlas post office) and 7 miles north of Barnesville, the nearest town on the Baltimore & Ohio Railroad. Waynesburg coal; thickness averages about 3 feet. The sample was cut in a dry place 200 feet south of the mine mouth. The bed was measured and sampled by Frank Reeves on November 24, 1914, as described below.

Section of coal bed in George Thomas's mine.

	20241	
	Ft.	in.
Roof, sandstone.		
Coal	1	0
"Sulphur"		a 2
Coal		10
"Soot"		a 1
Coal		11
Floor, shale.		
Thickness of bed	3	0
Thickness of coal sampled	2	9

a Not included in sample.

20234. Howard Brown's drift mine, locality 143, sec. 26, T. 6 N., R. 5 W., Wayne Township, Belmont County, 2 miles southeast of Somerton and 8 miles southeast of Barnesville, the nearest town on the Baltimore & Ohio Railroad. Waynesburg coal; average thickness about 2½ feet. The sample was cut in the mine at a point 100 feet west of the mine mouth. Although generally less than 3 feet thick and of high ash content, this coal is mined in a small way at numerous places for local use. The bed was measured and sampled by Frank Reeves on November 24, 1914, as described below.

Section of coal bed in Howard Brown's mine.

	20234	
	Ft.	in.
Roof, shale.		
Coal		6
"Sulphur"		a 1
Coal	1	
"Soot"		a ½
Coal		11
Floor, clay shale.		
Thickness of bed	2	6½
Thickness of coal sampled	2	5

a Not included in sample.

20174. J. D. Milhoan's drift mine, locality 128, sec. 7, T. 7 N., R. 5 W., Goshen Township, Belmont County, 1½ miles northeast of Hunter and 5 miles south of Bethesda, a village on the Baltimore & Ohio Railroad. Waynesburg coal; thickness fairly uniform, about 3 feet in this mine but varies considerably in other openings of the neighborhood. The coal is tough and somewhat bony, and although lacking visible clay bands has the appearance of being of high ash content, as is shown by the analysis. The bed was measured and sampled 50 feet south of the mine mouth by D. Dale Condit on November 21, 1914, as described below.

Section of coal bed in J. D. Milhoan's mine.

	20174	
	Ft.	in.
Roof, shale.		
Coal	2	1½
Bone		1½
Coal		11
Floor, shale.		
Thickness of bed	3	2
Thickness of coal sampled	3	2

20236. Stoffel mine, on the Nathan Davis farm, sec. 27, T. 5 N., R. 4 W., Washington Township, Belmont County, 1 mile southwest of Alledonia, a station on the Ohio River & Western Railroad. Waynesburg coal; thickness in this and neighboring

mines about 2½ feet. This coal is present throughout large areas in similar thickness. Its high ash content is objectionable, but it is a valuable source of fuel for local use. The bed was measured and sampled by D. Dale Condit on November 26, 1914, as described below.

Section of coal bed in Stoffel mine.

	20236	
	Ft.	in.
Roof, shale.		
Bony coal		4
Coal	a 2	5½
Floor, clay shale.		
Thickness of bed	2	9½
Thickness of coal sampled	2	5½

a Not included in sample.

WASHINGTON COAL.

20238. S. A. Moore's drift mine, extending about 50 feet into the hill at locality ..., sec. 33, T. 5 N., R. 4 W., Washington Township, Belmont County, 1½ miles southwest of Alledonia, a station on the Ohio River & Western Railroad. Washington coal. The bed shows the usual division into two benches separated by clay; the upper bench is the better. The section below is representative of the Washington coal throughout large areas. It is mined to only a slight extent, owing to its inferior quality, better coals being accessible in most places. The sample was taken from a room and showed little evidence of weathering. The bed was measured and sampled by D. Dale Condit on November 26, 1914, as described below.

Section of coal bed in S. A. Moore's mine.

	20238	
	Ft.	in.
Roof, shale.		
Coal, bony		a 3
Coal, bony in lower part	2	1
Clay		a 8
Coal		11
Floor, shale.		
Thickness of bed	3	11
Thickness of coal sampled	3	0

a Not included in sample.

LIMESTONE.

The Woodsfield and Summerfield quadrangles are more abundantly provided with limestone than almost any other part of southeastern Ohio. The beds are distributed at varying intervals through all the outcropping formations, thus affording a more or less convenient supply for every township in the area. The extent and accessibility of each bed are set forth in the description of the respective townships.

Uses of limestone.—The limestone beds are, with one or two exceptions, not suitable for the manufacture of Portland cement, being magnesian. By far the most important use to which they can be put is in the surfacing of the roads. Few regions are so favorably situated with reference to a convenient supply of such material, and it is to be hoped that this opportunity for inexpensive construc-

tion of good roads will be used to a great extent in the future. Go roads are of especial importance for the economic development of region such as that comprising Belmont, Monroe, and Noble counti where much of the hilly country is far from a railroad and some of still further isolated on account of rough topography.

Most of the limestone beds have a composition that makes th well suited for agricultural use. This is especially true of the An and Cambridge fossiliferous limestones, which appear in outcrop the Summerfield quadrangle and are represented on Plate XII. T Cambridge is 4 feet thick at Senecaville and at certain points w of Lore City. The Ames is persistently 1 to 2 feet thick. A sin analysis of a sample of the Ames limestone obtained near Senecav is given below. It is noteworthy that the rock contains a sn amount of tricalcium phosphate.

Analysis of Ames limestone from point near Senecaville.

SiO_2	12.72
Al_2O_3 includes about 0.5 per cent Fe_2O_3 and any titanium present)	4.20
MgO	.21
$CaCO_3$	79.10
P_2O_5	.48
	96.71

Loss on ignition, 36.38 per cent.

The most valuable limestone beds occur in the upper part of Conemaugh formation and the lower two-thirds of the Monongal formation. They are designated in the generalized section (fig p. 16), the Lower Pittsburgh, Upper Pittsburgh, Fishpot, and I wood limestones.

Lower Pittsburgh and Upper Pittsburgh limestones.—Immedia below the Pittsburgh coal is the Upper Pittsburgh limestone, and al 25 feet below that is the Lower Pittsburgh limestone. The Lo Pittsburgh is the thicker of the two, being 3 to 5 feet thick througl its outcrop in the area. It ordinarily consists of several beds, s as are illustrated in Plate II, and when seen close at hand shows pebbly surface also illustrated in the view. The texture is a phous or nearly so, and the rock, as its appearance would indic is a fairly pure limestone containing little magnesia, iron, or alum Two analyses of the rock are given below:

Analyses of Lower Pittsburgh limestone.

	Baileys Mills.	[illegible]
[illegible]	2.83	
[illegible] (includes [illegible] and any titanium that may be present)	1.05	
[illegible]	.87	
[illegible]	94.20	
	98.95	

Loss on ignition, [illegible] per cent.

The purity of the Lower Pittsburgh limestone suggests that it would find a good use in the manufacture of building lime. Being low in magnesia it may also be of value in the manufacture of Portland cement, especially when mined and combined with a calcareous clay that is commonly found below it.

Fishpot limestone.—The Fishpot limestone lies beneath the Lower Meigs Creek coal. It is nearly as abundant as the Lower Pittsburgh limestone, being 3 to 6 feet thick throughout nearly all of its outcrop in the area and locally as much as 13 feet thick, as described below. The upper beds are as a rule of gray color and purer than the lower beds, which are commonly buff and not so resistant to weathering. At the Maldine farm, 1 mile north of Barnesville, immediately beneath the Lower Meigs Creek coal is 7½ feet of hard blue or gray limestone with a small amount of shale (sample 1 in the table below). Next lower is 6 feet of buff or gray limestone (sample 2). The following analyses of this limestone are given in a report of the Geological Survey of Ohio.[12]

Analyses of Fishpot limestone from Maldine farm, near Barnesville.

[S. V. Peppel, analyst.]

	1	2
Silica	14.06	16.10
Alumina	4.33	5.74
Oxide of iron	1.13	2.28
Carbonate of calcium	66.31	51.25
Carbonate of magnesium	12.71	23.02
	98.54	98.39

Benwood limestone.—The Benwood includes numerous beds of limestone lying above the Meigs Creek coal and having a combined thickness of about 70 feet. The beds vary considerably in thickness and composition and are interbedded with strata that are more properly termed calcareous shale than limestone. The appearance of some of the beds is illustrated by Plate X, *B*. Another bed illustrated in Plate III, *B*, has a most peculiar aspect, resembling flint clay in texture and presenting everywhere on the outcrop a peculiar blocky surface as shown in the view. This layer is persistent and has a thickness of about 4 feet in nearly all of Belmont County. It lies 15 to 20 feet above the Meigs Creek coal. Its composition, as shown by the analysis of a sample taken at a point on Captina Creek near the east edge of the area, indicates that it should be called a calcareous magnesian clay.

[12] Orton, Edward, jr., and Peppel, S. V., The lime resources and the lime industry in Ohio: Ohio Geol. Survey Bull. 4, 4th ser., pp. 41-42, 1906.

Analysis of clay bed above Meigs Creek coal on Captina Creek.

SiO_2	25.70
Al_2O_3 (includes Fe_2O_3, P_2O_5, and any titanium present)	14.38
$MgCO_3$	21.47
$CaCO_3$	31.79
Loss on ignition 28.11 per cent.	93.34

Samples of the entire Benwood limestone member have been collected by the Geological Survey of Ohio at Armstrongs Mills, Belmont County. The analyses show the limestone to be of magnesian character, the percentage of magnesia ranging from about 13 to 17.[13]

The section and analyses are given below.

Section of limestone strata sampled at Armstrongs Mills.

		Ft.	In.
	Sandstone.		
	Shale interstratified with about one-fourth limestone	47	
	Limestone (roof)	3	
Sample 1	Shale, hard and calcareous	2	6
	Blue limestone, not very hard	1	
	Blue limestone, hard	3	
Sample 2	Shale	1	
	Limestone, impure and shaly	4	
	Blue limestone, hard	5	
	Shale		6
	Blue limestone	1	
	Shale		9
	Limestone	1	
	Green shale	4	
Sample 3	Gray limestone	3	
	Shale		6
	Buff limestone	4	
	Brown limestone, shaly	1	
	Dark-gray limestone	1	
	Blue shale	1	
	Gray limestone	2	6
Sample 4	Blue limestone	1	6
	Dirty limestone, hard, but laminated		6
	Light-brown limestone	2	
	Brown limestone	3	
	Blue limestone	6	
	Dark-brown slaty limestone	1	
	Soft slate	1	
	Coal, Meigs Creek	4	
	Interval, containing shale with a little sandstone	23	
	Limestone (roof)	2	
Sample 5	Blue limestone, hard, in four courses	8	
Sample 6	Hard fine-grained shale, bleaching to a light color on outcrop; Hard, fine-grained shale, very dark color	5	

[13] Ohio Geol. Survey Bull. 4, 4th ser., p. 43, 1906.

Sample 7..	Blue limestone	4	
	Shale, brown in part	1	
	Blue limestone	3	6

Thus it is seen that for about 50 feet above and below the Meigs Creek coal, the strata are predominantly calcareous. Whether a different grouping of the members would have made a materially different or better showing of the character of the materials is of course open to conjecture.

Analyses of limestone from Armstrongs Mills.

[S. V. Peppel, analyst.]

	1	2	3	4	5	6	7
Silica	29.16	25.88	17.10	25.46	10.20	26.10	17.02
Alumina	8.43	7.06	4.90	10.11	2.41	9.64	4.56
Oxide of iron	2.69	1.84	1.24	1.25	1.13	1.30	1.74
Carbonate of calcium	44.23	47.70	58.93	45.40	73.57	45.70	59.78
Carbonate of magnesium	13.56	15.84	16.87	15.53	12.19	15.45	15.98
	98.07	98.32	99.04	97.75	99.50	98.19	99.08

The proportions of lime and magnesia versus silica and alumina fluctuate reciprocally with the inclusion of more or less of the shaly strata, but in the case of sample 5, which contains no shale, the character of the limestone is clearly shown to have no field of usefulness in either white lime or Portland cement manufacture, though it might be of value for agricultural purposes. That it could be used for the Roman or natural cement is beyond doubt. Also other sections in the locality can undoubtedly be found in which limestone of good quality for Roman cement can be obtained, by exclusion of the shale intercalated with the stone beds. The introduction of the Roman cement industry into this section is, however, a question of economics rather than of mineral resources.

The information at hand indicates that the uses to which the limestones of the Monongahela formation may be put are few. None of the beds can be of much use for building. Most of the rock when burned for lime gives an undesirable gray color. The material does not seem promising for use in the manufacture of Portland cement. Hydraulic lime and Roman cement were at one time manufactured at Barnesville. These products are inferior to Portland cement for many purposes but are serviceable for foundations and rough stone masonry.

BUILDING STONE.

The only rock in this area of any value for building is sandstone. The principal sandstone members are in ascending order the one between the Lower Meigs Creek and Meigs Creek coals, the sandstone over the Uniontown coal, correlated with the Gilboy sandstone of the West Virginia Geological Survey, and the sandstone over the Waynesburg "A" coal, correlated with the Mannington sandstone of the West Virginia Survey. All these sandstones occur

locally in massive form and present numerous exposures suitable for quarrying. The rock is as a rule too friable to be regarded as superior material for building and on weathering readily wears away. The texture in massive exposures is fairly coarse, and the rock is as a rule a freestone well suited to easy quarrying. In the finer-textured sandstones the bedding is so commonly irregular or the lamination so pronounced that the rock shows a too ready tendency to break along the bedding.

The sandstone that has been most extensively quarried is the bed over the Waynesburg "A" coal along Standingstone Run near Woodsfield. The sandstone over the Uniontown coal has been used near Miltonsburg in the construction of a church. (See Pl. X, *A*.) Descriptions of these and other localities are given under the respective township headings.

CLAY AND SHALE.

Both clay and shale are present in great quantity in this area. So far as known they have not been utilized in the ceramic industry. It is certain, however, that material suitable for the manufacture of bricks and paving blocks can be obtained in almost any part of the area.

Numerous outcrops of the Washington formation near Woodsfield show clay that may upon investigation be found suitable for the manufacture of refractory wares. Two beds of clay were observed, one about 20 feet above and the other immediately below the Washington coal. They are of greenish-gray or gray color and apparently contain little lime or iron.

The alluvial silt so plentiful along Seneca Fork and other branches of Wills Creek will probably be found upon investigation to be suited to the manufacture of brick. The material varies in texture, being almost a clay in some places and of sandy composition in others. No attempt has been made to use such material in this area, but it has been successfully used in a small way at the village of Cumberland, near the center of the Cumberland quadrangle, to the west.

WATER RESOURCES.

The Woodsfield and Summerfield quadrangles contain no streams of large size. The largest are Captina and Sunfish creeks and their branches and Leatherwood Creek, Seneca Fork, and other tributaries of Wills Creek, all of which rise near the center of the area. The volume of even the largest streams is too small to make them of much value for power. In dry seasons they are reduced to mere trickles or water holes. It is probable that with the growth of communities in this area it will become more and more necessary to construct reservoirs for the storage of water.

A. SANDSTONE OVERLYING UNIONTOWN (COAL) HORIZON 2 MILES WEST OF MILTONSBURG.

B. TYPICAL EXPOSURE OF BENWOOD LIMESTONE ALONG BEND FORK NEAR CAPTINA CREEK.

Both Barnesville and Woodsfield obtain their water supply from springs. The flow is caught in reservoirs and pumped to tanks on hilltops within the towns. The supply of Woodsfield is obtained from a ravine 2 miles north of the town and about 200 feet lower, from which it is pumped to a tank on a high hill at the north side of the town and 100 feet higher thus giving a good head.

The water supply of the farming communities is derived largely from springs, which are numerous and for the most part persistent even in periods of drought. The springs were chosen as convenient home sites by the early settlers, and therefore nearly every farm house except those on the ridges has its spring close at hand.

In digging or drilling water wells in the valleys it is rarely necessary to go deeper than 10 or 20 feet in order to obtain a good supply. A few wells penetrate to a considerable depth in bedrock. A well drilled near the station at Lore City obtains a sulphurous water in black shale at a depth of about 60 feet. In the valley near Hall School, 1 mile southwest of Quaker City, a supply of excellent water is obtained at several farmhouses by digging to the Ames limestone, which is found at depths ranging from 10 to 30 feet. The sandstone and other strata almost without exception contain salty water where encountered at a depth of 75 feet or more in the valleys, thus furnishing evidence as to the shallow depth of circulation of ground waters.

Water in quantity sufficient for domestic use can be obtained at moderate depth on almost any of the ridges. It is usually associated with a coal or limestone bed or occurs in a sandstone underlain by clay. It is exceptional to find on the ridges a well as deep as 75 feet, and the greater number are 50 feet or less in depth.

GEOLOGY BY TOWNSHIPS.

GUERNSEY COUNTY.

MILLWOOD TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Millwood Township lies at the east side of Guernsey County, adjacent to Warren Township, Belmont County. Leatherwood Creek, which heads in Warren Township near Barnesville, flows westward across Millwood in a direct route to Cambridge and its valley is utilized by the Baltimore & Ohio Railroad. Quaker City and Salesville are the principal villages. Baileys Mills, a coal-mining community at the Belmont County line, is rapidly increasing in size. The number of inhabitants in the township in 1920 was 1,742, and in Quaker City, the largest village, 732.

The surface of Millwood Township is more rugged than that areas to the east or west. Its hilltops agree in elevation with th of the highlands to the east, along the divide separating the wat of the eastward-flowing Captina Creek from those of streams tl flow westward into Tuscarawas River. The surface is, howev dissected by deep valleys with numerous tributary ravines. Leath wood Creek is joined by a number of creeks from the north wh are longer and larger and more numerous than those from the sou The elevation of the principal valleys ranges from 840 to 900 f above sea level, and that of the ridges from 1,150 to slightly m than 1,300 feet.

GEOLOGIC SECTION.

The Pittsburgh coal bed is the principal geologic horizon mar in Millwood Township, and the name is a household term because the extent to which the bed has been mined by the farmers. Quaker City it lies about 205 feet above the railroad, or 1,080 f above sea level, but it gradually descends eastward to 1,030 feet Baileys Mills. Another coal bed about 100 feet higher, the Me Creek, is seen in the hills in the east side of the township north the railroad.

From Spencers Station westward along the valley the Ar ("Crinoidal") limestone, with its abundant fossil shells, appears outcrop. In the railroad embankment at the east side of Qua City it is a few feet above the railroad track, and 2 miles west, in vicinity of Salesville, it crops out along the sides of the hills 40 f above the railroad. It is a single brownish-gray layer about 2 f thick and can not be mistaken, because of its fossil-scarred surf and the absence of other limestone beds in this part of the geolo section. Below the Ames limestone is clay or shale of olive-gr and brownish-red to chocolate color, with scattered nodules of li stone and "ironstone" concretions. The strata above the Ames about 50 feet consist of sandy shale and thin-bedded sandstone, wh are in turn overlain by alternating beds of clay and shale of variega color and sandy beds.

The interval between the Ames limestone and Pittsburgh coa about 188 feet. In the upper part of the interval, about 25 f below the Pittsburgh coal, is the Lower Pittsburgh limestone mottled ochreous-yellow and gray rock about 4 feet thick. A l prominent bed, the Upper Pittsburgh limestone, lies immediat beneath the coal.

The strata in the interval of 100 feet between the Pittsburgh a Meigs Creek coal beds consist largely of sandstone or sandy sh with two or three prominent limestone beds. Sandstone commo occurs a little above or in contact with the Pittsburgh coal and a

about 80 feet above. This upper sandstone member in its most prominent development in the hills north and east of Quaker City is a massive bed 30 to 40 feet thick which extends above the usual position of the Meigs Creek coal. In such areas that bed is of little value and where present consists of an impure shaly coal 125 to 140 feet above the Pittsburgh coal and resting on the sandy beds.

STRUCTURE.

There is little regularity in the direction of dip of the beds in Millwood Township. In general it is southward, but there are local flexures that produce considerable variation. The rate of dip also varies, ranging from only a few feet to 40 feet in a mile. The rocks, as shown by the contour map (Pl. XII, in pocket) have the greatest dip east of Spencers Station, northwestward to Quaker City and beyond they lie nearly flat. At the east side of the township the rocks rise in a true anticlinal fold within which is the Barnesville oil and gas pool.

MINERAL RESOURCES.

COAL.

PITTSBURGH COAL.

The Pittsburgh coal lies well up in the long, narrow ridge of Millwood Township 150 to 200 feet above the valley and therefore will not be in great demand for exploitation in a commercial way except possibly in the eastern part of the township. The coal, although of fair thickness, is higher in sulphur and ash than the same bed where mined to the east along Ohio River and is therefore less desirable for certain purposes. Its chemical properties and heating value have been determined from samples taken in the Sayre mine, 1½ miles northwest of Quaker City (locality 1, sample 20178), and in the Cochran No. 2 mine, at Baileys Mills (locality 8, samples 20187, 20188). The results are tabulated on page 39. The thickness of the bed at these localities is shown by sections on Plate V.

In the vicinity of Baileys Mills and also farther west, near Quaker City, sandstone or clay "horses" locally reduce the thickness of the coal and give considerable trouble in mining. Where the coal is immediately overlain by sandstone the quality of the coal is noticeably poorer, there being an increased amount of "sulphur" and bony impurities, especially in the upper portion of the bed.

In the hills south of Spencers Station mines have been opened in a number of places, and the thickness of the bed is similar to that found on the north side of Leatherwood Valley. To the west, however, opposite Quaker City (locality 2), the bed thins from 4 feet to a few inches within a distance of half a mile. The bed is of doubtful

value in the hill above Hall School, but to the northeast, across the ridge (locality 3), it has a good thickness and has been mined for many years. Although geologically due in secs. 25 and 31, the coal is represented there by only a faint carbonaceous streak.

MEIGS CREEK COAL.

The Meigs Creek coal, so far as known, has not been mined in Millwood Township. Its thickness near the east township line is 2 to 3 feet for 2½ miles north of Baileys Mills and becomes increasingly greater nearer Barnesville, where the coal has been mined at several places. In the northeast corner of the township the coal is impure and deserves the name of bone rather than coal where seen in roadside outcrops at several places on the east-west ridge road. The bed lies in sandy shale above a thick sandstone, and its position is about 135 feet above the Pittsburgh coal.

The record of a well drilled on the J. K. Rose farm, 1 mile north of Salesville, is of interest on account of the several coal beds recorded. Their thicknesses as given must of course be regarded as rough approximations. The Upper Freeport coal, which should appear about 255 feet below the Ames limestone, is missing. Of the lower coal beds recorded, the first two may be the Lower Kittanning and the Clarion.

Log of well drilled for oil on J. K. Rose farm, 1 mile north of Salesville.

[Well head 25 feet below Ames limestone and 215 feet below Pittsburgh coal. Well nonproductive.]

	Thickness.	Depth.
	Feet.	*Feet.*
Shale, red	50	50
Sand, Cow Run		75
Limestone, Cambridge		95
Coal [probably Brush Creek]	1½	175
Shale, sandy		375
Coal [Lower Kittanning]	4½	379
Sand, Second Cow Run		390
Coal	3½	400
Coal	5	440
Coal	1½	510
Shale, sandy		600
Sand, stray		700
Sand, Keener		850
Sand, Big Injun		980
Sand, Berea	50	1,330-1,380

LIMESTONE AND SANDSTONE.

The Ames limestone appears in outcrop along the sides of Leatherwood Valley at Spencers Station and westward. Although 2 feet or less in thickness, the rock has been used for road metal where it is easily accessible. This rock, together with the limestone below the Pittsburgh coal, has been used in the construction of a pike between Salesville and Quaker City and also southward from Quaker City toward Batesville.

The most valuable beds are the Upper Pittsburgh and Lower Pittsburgh limestones, which lie 1 and 24 feet respectively below the Pittsburgh coal. The lower bed is the thicker, being 3 feet thick in Millwood Township and increasing southward to 5 feet or more in adjoining areas. The rock is brownish gray to nearly white and of suitable composition for making lime for use in agriculture.

A massive coarse-grained bed of sandstone 25 to 40 feet thick is conspicuous north and east of Quaker City to the township line. It lies about 75 feet above the Pittsburgh coal, near the hilltops. The rock has been quarried in a small way at numerous places for foundations, and years ago was taken out near Barnesville for railroad ballast. It is apparently sufficiently durable to have prospective value as a building stone, and favorable quarry sites can be found in almost every ravine.

Other sandstone beds of finer texture and not so massive are found 25 to 100 feet above the Ames limestone. The rock is in beds 1 to 3 feet thick, with even horizontal partings that give it a flaggy character.

RICHLAND TOWNSHIP.

Richland Township, in addition to being rich agriculturally, as its name implies, is an important mining region, commercial mines being in operation at Senecaville and Blacktop. The main line of the Baltimore & Ohio Railroad crosses its northeast corner, and a branch extends from Lore City southward across the township to Senecaville and other places to the west. The population of Senecaville in 1920 was 947 and of Lore City, part of which is in this township, 784. The total number of inhabitants in the township is given at 2,322.

SURFACE FEATURES.

Both Leatherwood Creek and Seneca Fork, the principal streams, have broad bottoms in which they flow in meandering courses. The Seneca Fork valley is along much of its course, half a mile or more wide, but for a short distance in the vicinity of Senecaville it is constricted by a thick layer of sandstone that forms the valley walls. The gradient of the valley downstream from Senecaville is about 3 feet to the mile, and that of the stream channel along its complicated meanders probably less than 1 foot to the mile.

The elevation of Seneca Valley at the southwest side of the township is about 800 feet above sea level. The neighboring hills rise 100 to 200 feet above the valley, and a few isolated summits rise slightly more than 300 feet. Eastward there is an increasing number of high hills, and near the township line east of Fairview School the general elevation along the ridges is from 1,100 to about 1,250 feet above sea level.

GEOLOGIC SECTION.

The strata that crop out in Richland Township for the most pa belong to the Conemaugh formation. The higher hills in the easte part of the area consist of basal beds of the overlying Monongahe formation. There are no coal beds of more than local importan and the rocks for the most part consist of sandy shale, brownish-r clay, sandstone, and thin beds of limestone. The Upper Freepo coal, mined by shafting, is 100 feet or more below the bottoms of t valleys.

The Cambridge limestone crops out along the valley of Leatherwo Creek. At Blacktop its position is about 60 feet above the vall or 877 feet above sea level. In this vicinity the bed is about 3 f thick and consists of one layer. The freshly broken rock is blui gray and smooth textured. Fossil shells are abundant, the m characteristic one being a form called *Chonetes verneuilanus*. Lore City the limestone is less prominent, being an impure yellow nodular rock, but the fossils are as abundant as elsewhere. T Cambridge limestone is most prominent at Senecaville, where it 4 feet thick. It may be seen near the railroad station and also at t abandoned shaft a few hundred yards north, where the bed is 1 feet above the Upper Freeport coal. Westward, down Seneca Fo the bed is only slightly thinner, but to the north, along Soggy R it loses its prominent character and consists of limestone nodu that are seldom seen in good exposure. The position of the bed everywhere indicated by the Anderson coal, 10 feet higher.

The Ames limestone, although nowhere as thick as the Cambrid is remarkably persistent and appears as a single bed 1 to 2 feet th throughout the region. As shown in the general section, it lies ab 110 feet above the Cambridge limestone; therefore the extent of outcrop, as represented on the map (Pl. XII, in pocket), is mu greater. Being so easily recognized, it is useful in determining geologic structure—that is, the direction and rate of dip of the roc The contours on the structural map (Pl. XII) are drawn from h dreds of elevations obtained on the Ames limestone and other strata.

The succession of strata below the surface at Gibson is shown the following excellent well record, furnished by John Shane, driller. The well head is 77 feet below the Ames limestone. coal at a depth of 123 feet is probably the Brush Creek, and that 262 feet is probably the Middle Kittanning.

Log of well No. 65 on Z. Tennant farm at Gibson.

[Nonproductive.]

	Thickness.	Depth.
	Feet.	*Feet.*
[illegible] material and clay	40	40
[illegible]	10	50
[illegible]	10	60
[illegible]	15	75
[illegible]	30	105
[illegible]	17	122
[illegible]h Creek?]	1	123
[illegible]	13	136
[illegible]	7	143
[illegible]	2	145
[illegible]hite	5	150
[illegible], dark	10	160
[illegible]	19	179
[illegible]	11	190
[illegible]	70	260
[illegible] Middle Kittanning?]	2	262
[illegible]	4	266
[illegible] show of oil	154	420
[illegible]	30	450
[illegible]	7	457
[illegible]	13	470
[illegible]	70	540
[illegible]	35	575
[illegible]	75	650
[illegible]	5	655
[illegible]	10	665
[illegible]	68	733
[illegible]	4	737
[illegible]	26	763
[illegible]	130	893
[illegible]	45	938
[illegible]	274	1,212
[illegible] black	45	1,257
[illegible] Berea, hard, compact	46	1,303

STRUCTURE.

The dip of the strata in Richland Township is in general southeast, [illegible] there are numerous local cross flexures or folds that cause varia-[illegible] in the direction of dip and produce synclinal "embayments" [illegible] anticlinal "noses." The most unusual structural feature is the [illegible]pression at the east side of Lore City. The evidence upon which [illegible] mapped consists of elevations of the Cambridge limestone. That [illegible] is 846 feet above sea level at the road forks half a mile north of [illegible] village, 847 feet on the main street 700 feet south of the railroad, [illegible] 802 feet on the railroad half a mile east of the station. In ad-[illegible]ent hills to the north and south of this place the limestone lies [illegible] 50 feet higher.

MINERAL RESOURCES.

Among the mineral products of Richland Township are oil and [illegible], coal, limestone, and sandstone. Oil has been found in small [illegible]ntities, and most of it comes from the Mahoning sandstone, over-[illegible]ng the Upper Freeport coal. In fact, that bed is saturated with [illegible], which runs into some of the mine workings and has been pumped [illegible] sold as crude oil. In other places the sand contains little oil [illegible] a large amount of salty water.

COAL.

UPPER FREEPORT COAL.

The Upper Freeport coal bed is mined by shafts at Senecaville and Blacktop. A mine formerly operated at Kings, north of Blacktop, has been abandoned for many years. At Blacktop the bed is about 100 feet below the valley, and at Senecaville about 170 feet.

The Blacktop mine, 1 mile west of Lore City, is operated by the Morris Coal Co. The average daily output of run-of-mine coal is reported to be 1,000 tons. The coal was sampled at two points (analyses 20264, 20265, p. 38). Sections of the coal bed measured at two points in the mine are given on page 42. The mine workings have extended to the southeast, south, and southwest, a distance of a little more than 1 mile. To the north and northwest the coal has been tested at a number of places and is believed to be a continuous thick bed. In the valley of Leatherwood Creek there is some question as to the possibility of extracting the coal, owing to an insecure roof. The alluvium is many feet thick, and in Center Township, a short distance downstream from the vicinity of Blacktop, it rests directly on the coal.

The Cleveland mine of the Morris Coal Co. is at the southeast side of Senecaville on a spur from the Baltimore & Ohio Railroad. The bed was measured and sampled at two points (analyses 20261, 20262, p. 38). Measurements of the bed are given on page 43. The mine workings extend northeast and south from the shaft a distance of about 1 mile. A little more than half a mile to the southwest is a sandstone "roll," which has checked development in that direction. The sandstone roof abruptly slopes down, entirely replacing the coal along a front bearing nearly northwest.

East of the mine workings at Senecaville many diamond-drill holes have been put down, and there is assured a considerable area of valuable coal. In one of the test holes so much oil was found in the sandstone above the coal that it was pumped out and sold for crude oil.

ANDERSON COAL.

The Anderson coal ranges from a mere blossom to a bed about 2 feet thick. Almost the only exposures available for measurement in this township are natural outcrops on the roads, but at a few places the bed has been mined by stripping or drifting into the hillsides. The principal places where it may be as much as 2 feet thick are half a mile west of Blacktop and about 3 miles to the south, on Soggy Run. Near the Waldhonding mine, just across the Valley Township line, where the bed is mined for local use by Andy Slovak, it is 1 foot 10 inches thick. The results of an analysis are given on page 39 (analysis 20243).

SANDSTONE AND LIMESTONE.

The only sandstone of probable value for building in Richland Township lies above the Cambridge limestone. It ranges from shaly to massive and coarse grained and in the latter form is prominently shown at Senecaville and eastward for 2 miles. The rock is conspicuous northward from Senecaville along the railroad and also between Lore City and Gibson, on the south side of the valley. Here and there small amounts of sandstone have been quarried for use in foundations.

None of the roads of Richland Township have been surfaced with limestone. About 1 mile of limestone pike has been built along the valley east from Lore City, and this is the only improved road in the region. Limestone that is easily available is somewhat scarce, the Ames and Cambridge beds being the only source in the western half of the township. The Ames limestone is persistently 1 to 2 feet thick, and by stripping on the outcrop large quantities can be obtained. The Cambridge limestone is of local importance, being 4 feet thick west of Blacktop and in the vicinity of Senecaville, but elsewhere it is simply a layer of nodular clayey limestone. The outcrops of the Ames and Cambridge limestone beds are represented on the map (Pl. XII, in pocket), and their positions in the geologic column are shown in the general section.

About 170 feet above the Ames, at the base of the prominent terraced slopes that extend to the tops of the hills in the eastern part of the township, is the Lower Pittsburgh limestone, a bed 2 to 4 feet thick, of light-gray color and smooth texture, probably suited for burning for building lime and certainly useful for agriculture.

WILLS AND CENTER TOWNSHIPS.

A strip of land slightly more than 1 mile in width at the south sides of Wills and Center townships is included within the Summerfield quadrangle. The valley of Leatherwood Creek lies parallel to the south boundaries of these townships and is followed by the Baltimore & Ohio Railroad. At the adjoining south corners of the two townships is Lore City, the principal village. A branch railroad line was built from Lore City northeastward a distance of 4 miles to Washington and operated for a short time but is now idle.

GEOLOGIC SECTION.

The rocks exposed in the southern parts of Wills and Center townships consist almost entirely of rusty brown or brownish-red clay, shale and sandy shale, with sandstone beds of irregular extent and thickness, and a few thin layers of coal and limestone.

One of the lowest horizon markers in the area is a coal bed known as the Anderson (Bakerstown). Where seen in a ravine at Kings

Mine it is about 1 foot thick and has a roof of irregular-bedded sandstone. Its position is about 80 feet above the railroad and 155 feet above the coal at the bottom of the shaft. About 10 feet beneath the Anderson coal is the Cambridge limestone, a bed about 3 feet thick, containing many fossils. Its outcrop was seen at numerous places on both sides of Leatherwood Valley near Blacktop and Kings Mine. To the east near Lore City, however, the bed is much less prominent, being made up of nodular lumps of impure limestone embedded in calcareous clay.

Near Lore City and northward is a coal bed about 25 feet above the position of the Anderson coal. Where seen at the forks of the road half a mile north of the village and to the northeast along the abandoned railroad it is about 1 foot thick and lies in the midst of an irregular bedded sandstone. In the same vicinity the Cambridge limestone was found 35 feet lower.

In the southern part of Wills Township the Ames fossiliferous limestone bed is 109 feet above the Cambridge. It lies at the top of a bed of brownish-red clay and is overlain by light greenish-gray shale. This bed is persistent throughout the region, being absent at only a few places. Although only 1 or 2 feet thick, it is conspicuous in roadside and ravine outcrops, owing to its association with soft shale and clay. The strata for more than 100 feet above the Ames limestone are of variable character but consist largely of sandy shale, thin-bedded sandstone, and greenish-gray or chocolate-colored clay.

MINERAL RESOURCES.

COAL.

The only coal of economic importance in the portions of Center and Wills townships here described is the Upper Freeport bed, which lies about 50 feet below the valley of Leatherwood Creek at the extreme northwest corner of the Summerfield quadrangle. It is probable that the coal is persistently 5 feet or more thick throughout large areas west and north of Lore City. Considerable coal has been mined at Kings Mine, but the site was abandoned years ago, after a fire had destroyed the buildings about the shaft. Westward from Kings Mine along Leatherwood Valley mining operations will be impossible, at least in places, owing to the thickness of alluvium which extends down to the coal.

Many coal test holes have been drilled in the northern part of Wills Township, in the Antrim quadrangle, near Washington and eastward along Salt Fork. The results have almost without exception proved unfavorable, the coal being thin or lacking. A record of the strata penetrated on the G. M. Coen farm, near the center of sec. 20, 1 mile south of Washington, furnished by Prof. F. A. Ray, is given *below:*

Record of core-drill boring on G. M. Coen farm, sec. 20, Wills Township.

	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Surface	4		4	
Lime	2		6	
Shale, blue	28		34	
Slate, dark	38		72	
Coal	1		73	
Clay	3		76	
Shale, sandy	22		98	
Slate, black	1		99	
Coal		6	99	6
Clay		6	100	
Lime	30		130	
Slate, light	6		136	
Clay	4		140	
Lime	33		173	
Coal		8	173	8
Clay	5	4	179	
Lime, sandy	39		218	
Slate, dark	22	7	240	7
Slate, black		6	241	1
Coal, "No. 6" or Middle Kittanning	3	3	244	4
Clay	1	1	245	5

LIMESTONE AND SANDSTONE.

The principal limestone beds are the Ames and Cambridge, which have already been described. Neither is more than 2 or 3 feet thick, but the amount of rock that can be obtained by stripping in ravine outcrops is considerable and should go far toward surfacing the principal roads of the townships.

The only sandstone bed of possible value for quarrying is the one above the Anderson coal. The rock is as a rule irregularly bedded and friable, but in a few favored localities it has been found suitable for foundations. The stone has been quarried to a slight extent on the abandoned railroad about 1 mile northeast of Lore City.

NOBLE COUNTY.

WAYNE TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Wayne Township, Noble County, is an irregular area lying in the north-central part of the Summerfield quadrangle. A portion of the township is within the bounds of an early United States military reserve. Kennonsburg, the only village, has a population of a few dozen people, and the total number of inhabitants in the township according to the census of 1920 was 438. This township, like most other rural communities, is decreasing in population, the number in 1910 (479) being 32.3 per cent less than in 1890, when it had 708 people. The west end of the township extends almost to the railroad at Senecaville, and the north side is about 1¼ miles from Salesville, on the Baltimore & Ohio Railroad.

The most unusual feature of the surface of Wayne Township is the abnormally broad valley of Seneca Fork of Wills Creek, a comparatively small stream whose flood plain is nearly as broad as that of the Ohio at Wheeling. The stream has so slight a fall and its course is so meandering that the run-off after heavy rains is slow, and as a result the bottomlands are frequently flooded and are therefore of limited agricultural value. The lowlands and gently sloping hillsides are generally covered with a mantle of sandy loam which covers most rock exposures up to an elevation of about 920 feet. The sandy loam contains stream-rounded pebbles, even where it lies 100 feet above the flood plain of Seneca Fork. The depth to bedrock in the valley is probably many feet, and the alluvium, together with the mantle of similar material on the hillsides, probably denotes a former silting up of the valley to a depth of 150 feet or more. A similar condition is found throughout this drainage system. In the Tuscarawas Valley about 40 miles to the northwest, the rock floor is buried several hundred feet below the river channel.

The land rises in gentle slopes 300 to 400 feet above the valley and forms rounded ridges that show little concordance in elevation. The highest hilltops, which are along the north side of the township are 1,240 to 1,280 feet above sea level. The hillsides consist of a number of terraces that vary in steepness according to the hardness of the underlying strata. Sandy shale is more resistant to weathering and wear by streams than clay or shale, which in addition to easy erosion are much given to landslides.

GEOLOGIC SECTION.

There are two strata which deserve first consideration in a description of the rocks of Wayne Township, owing to their easy identification, economic value, and use in the mapping and study of other geologic features. They are the Ames limestone, which crops out low in the hills in the western part of the township, and the Meigs Creek coal, which lies in the higher hills in the eastern part. The vertical interval between these beds is about 315 feet. The gentle southeasterly dip carries the Ames limestone below the bed of Seneca Fork of Wills Creek opposite Kennonsburg, as shown on Plate XI in pocket. In its westward outcrop the bed is everywhere 1 to 2 feet thick and contains crinoid stems and fossil shells, which serve to distinguish it from all other limestone beds.

The strata for 150 feet above the Ames limestone consist chiefly of sandy shale, a few sandstone layers, and beds of greenish-gray or brownish-red shaly clay. The succeeding 150 feet upward to the Meigs Creek coal contains several masses of tough sandy shale 30 to 40 feet thick, between which are thin beds of limestone and clay.

STRUCTURE.

The general southeastward dip of the rock beds of this region is varied in the western part of Wayne Township by a low up-fold called the Chaseville anticline, which trends northeast. It is paralleled on the northwest by a shallow depression, and on its southeast side the normal southeasterly dip of 20 to 40 feet to the mile is resumed. Other flexures of less prominence appear in the northern part of the township. These structural features are represented on Plate XII.

MINERAL RESOURCES.

Wayne Township is unimportant as a producer of oil, gas, or coal. A few oil wells at the north end of the Chaseville field lie within the township, and oil has been found in small amounts at other places.

COAL.

The Meigs Creek coal, which is the only bed of minable thickness in the rocks that crop out, is of slight extent, lying in the tops of the hills in the eastern part of the township. The coal bed of greatest value is the Upper Freeport, which is mined by shafts to a depth of about 200 feet at Senecaville.

UPPER FREEPORT COAL.

The mine workings of the Cleveland mine at Senecaville extend into the west end of Wayne Township. The thickness of the coal, as shown by the section on page 43, measured 5,000 feet east of the shaft about 2,000 feet north of the Wayne Township line, is nearly 6 feet. The southward extension of the mine workings has demonstrated the presence of a sandstone "roll," which replaces the coal along a front extending in a southeasterly direction across sec. 6. The bed is missing in many wells drilled for oil and gas to the south, in the Chaseville pool. Little is known concerning its character in the eastern part of Wayne Township. It has been tested by core drilling at several points, as shown on Plate XII, but no records were obtained

MEIGS CREEK COAL.

The Meigs Creek coal appears as a roadside blossom at many places near Longs School, in the northeast corner of the township, and has been mined in a small way at several places. Its thickness is a little more than 3 feet, and a thinner rider coal lies above it, separated by foot of clay. In the C. Long mine (locality 55, Pl. VI), a quarter of mile east of the township line, a thickness of 4 feet 5 inches of coal was measured. To the south, in the ridge near the township line, the bed has been mined at a few places, and the thickness is reported to be 4 feet.

SANDSTONE AND LIMESTONE.

There is a little sandstone suitable for building or rough founda tions in Wayne Township. The principal bed lies below the Meig Creek coal, and is of some prominence in the vicinity of Longs Schoo and elsewhere in the eastern part of the township, where it is 20 t 30 feet thick, but so friable that it is easily crumbled into sand Another sandstone bed occurs a little above the Lower Pittsburg limestone, but it is as a rule shaly and thin bedded.

The Ames limestone, a bed 1 to 2 feet thick, crops out in the valle of Depue Run north of Kennonsburg and gradually rises in the hill on the west. The bed constitutes almost the only limestone suppl in that area, with the exception of several layers near the hilltops i the vicinity of Miley School.

The amount of limestone in the eastern part of the township greater, there being three beds 2 to 3 feet thick distributed in th section 30 to 130 feet below the Meigs Creek coal. The princip layer is the Lower Pittsburgh, whose outcrop forms a conspicuou band of white nodules along the hillsides. It is everywhere 2 to feet thick. Its prominent outcrops in the ravines furnish easil accessible supplies of material for road surfacing.

BUFFALO AND VALLEY TOWNSHIPS.

LOCATION AND SURFACE FEATURES.

The eastern third of Buffalo Township and about 1 square mile Valley Township lie within the Summerfield quadrangle. Th Cleveland and Marietta branch of the Pennsylvania Railroad cross the western part of these townships, in the Cumberland quadrang and on it are the villages of Glenwood, Ava, and Pleasant City.

The waters of the two townships are carried off by Buffalo Cree Seneca Fork of Wills Creek, and their tributaries. Those strea flow northwestward and empty into Wills Creek. Their valleys, li those of all streams of this drainage system are unusually wide a the streams are sluggish. The elevation is about 790 feet in t valley of Buffalo Creek at the north edge of Buffalo Township. T hilltops are generally 1,000 to 1,100 feet in elevation, there bei many flat areas at 1,000 to 1,040 feet. Some of the highest summ in the northeastern part of Buffalo Township rise as high as 1,1 feet.

GEOLOGIC SECTION.

The outcropping strata mostly belong to the Conemaugh form tion and consist largely of brownish-red shale and clay with no persistent sandstone beds and a few layers of limestone. Limesto and sandy shale of the Monongahela formation form the conspicuo terraced hilltops in the eastern part of Buffalo Township.

The Ames limestone is the lowest outcropping stratum worthy of note. It is a fossiliferous brownish-gray layer 1 to 2 feet thick. Elevations obtained on its outcrop at numerous places furnish evidence regarding the attitude of the rocks. The outcrop of the limestone is a prominent spring line, owing to the impermeable clay associated with it. The overlying strata consist of sandy shale of olive-green color. Beds to a height of 150 feet above this shale consist largely of rusty-brown sandy shale and brownish-red clay which form gentle hillside slopes.

In Valley Township the Cambridge limestone, 109 feet below the Ames, is exposed. The bed is not as thick here as to the northeast, near Senecaville. About 10 feet above it is the Anderson coal, which has been mined in the village near the Waldhonding coal mine.

The several limestone beds that appear in the hilltops at the east side of Buffalo Township lie 150 to 250 feet above the Ames limestone. None of them are more than 2 to 4 feet thick, and each is separated from the next by 25 to 40 feet of tough sandy shale to which in large part are due the conspicuous steepened hillside slopes.

MINERAL RESOURCES.

A portion of the Chaseville oil and gas pool lies in the northeastern part of Buffalo Township. The outcropping strata include no coal beds of considerable economic value, the only one being the Anderson, which is 1½ to 2 feet thick in Valley Township. The township is, however, underlain by a considerable area of minable Upper Freeport coal, the same bed as that mined at Senecaville and at several places on the Cleveland and Marietta branch of the Pennsylvania Railroad. Its depth below the Ames limestone is about 265 feet. The bed is recorded in some of the wells in the Chaseville oil field and has also been found in several hollow-rod drill holes in secs. 12 and 13. It is extremely variable in thickness and subject to abrupt changes; therefore no areas in which it occurs can be considered as of proved value until thoroughly tested with the drill.

The principal limestone and sandstone beds lie in the high hills in the eastern part of Buffalo Township. The sandstone may be of more or less value locally for use in foundations. The limestone furnishes an easily accessible source of material in moderate quantity for road building.

SENECA TOWNSHIP.

Seneca Township includes all but the two north rows of sections of T. 8 N., R. 8 W., as designated in the original land survey. Mount Ephraim and Chaseville are the only villages. The nearest place on the Ohio River & Western Railroad is Mount Ephraim Station, 1½ miles south of the village of Mount Ephraim. Senecaville, on a

branch of the Baltimore & Ohio Railroad, is 3 miles north of Chaseville. The population of the township according to the census report for 1920 was 616. The mineral resources include an oil and gas field at Chaseville and a bed of coal mined by shafts at numerous places in the township.

SURFACE FEATURES.

The principal valleys of the township are broad and of low gradient, the fall being only 2 or 3 feet to the mile. This general character of the valleys of the trunk streams also marks those of the numerous small tributaries, which rise in the ridge that forms the principal divide, extending from Chaseville to Mount Ephraim and thence southeastward to Summerfield. The hilltops are rounded and have summits of varying elevation, there being no level upland. The altitude on the divide ranges from 1,100 to 1,260 feet above sea level, and the highest point is in the vicinity of Mount Ephraim. The lowest valley bottoms along the north side of the township have an elevation of about 830 feet. The rocks of the area consist largely of sandy shale alternating with clay and limestone beds, which constitute the higher hills. Below these are red clay and shale with few sandstone layers, which are so weak that landslides are prevalent. Such strata form gentle slopes that steepen abruptly at the beginning of the overlying tough sandy shale, whose resistant character produces the terraces so typical of this region.

GEOLOGIC SECTION.

The lowest easily recognized stratum at the surface in Seneca Township is the Ames limestone. Its outcrop is limited to the valleys of North Fork of Buffalo Creek in sec. 30 and Opossum Run east of Chaseville, as shown on Plate XII (in pocket). The limestone is only 1 foot or so thick but has abundant fossil shells.

Above the Ames limestone are sandy shale, nonpersistent sandstone, and red clay, with nodules of white limestone and hematite. The beds, with the exception of the basal 50 feet, are as a whole weak and much given to landslides. About 150 feet above the Ames limestone is the Lower Pittsburgh limestone, a gray rock 2 to 3 feet thick, of smooth, homogeneous texture, lacking fossil shells such as are found in the Ames. Higher strata consist of other limestone beds at intervals of 25 to 40 feet, between which are resistant sandy shale. The coal bed mined at many places in the area is the Meigs Creek. Its position is 120 to 140 feet above the Lower Pittsburgh limestone, or 270 to 290 feet above the Ames limestone. Over the coal is sandy shale, sandstone, or locally clay shale and limestone.

STRUCTURE.

The dip of the rocks is in general southeastward at a rate ranging from 10 to 40 feet to the mile. The axis of the Chaseville anticline, a low fold, extends in a northeasterly direction through Chaseville, and along it is the Chaseville oil and gas field. The oil and gas produced here are derived largely from the Berea sand, which has also recently proved to be productive in sec. 22, 1½ miles northeast of Mount Ephraim.

MINERAL RESOURCES.

Coal, oil, and gas are the most valuable mineral products in Seneca Township. The township also contains sandstone for use in building and limestone for surfacing the roads.

COAL.

The Meigs Creek is the only minable coal bed at the surface in this township. The Pittsburgh coal, whose position is about 108 feet lower, or 25 feet above the Lower Pittsburgh limestone, is lacking here and in adjoining townships.

UPPER FREEPORT COAL.

The Upper Freeport coal, mined at Senecaville by shafts, may underlie parts of Seneca Township in minable thickness, but this fact can only be determined by extensive testing with the core drill. The bed is reported in a few wells in the vicinity of Chaseville, but is lacking in most of the oil and gas field.

MEIGS CREEK COAL.

The outcrop of the Meigs Creek coal bed is shown on Plates VI and XII. The bed is about 1,050 feet above sea level in the southeast corner of the township and rises northwestward to the tops of the highest hills a mile or so beyond Mount Ephraim. The thickness of the bed is illustrated by the following sections:

Sections of Meigs Creek coal bed in Seneca Township.

Mine on H. Morgan farm, SE. ¼ sec. 26 (locality 41).

	Ft.	in.
Shale.		
Coal, shaly		11
Clay		5½
Coal	1	7
Clay		1
Coal	1	3
Clay shale, unmeasured.		
Thickness of coal bed	4	3½

Mine on Mendenhall farm, SE. ¼ sec. 22 (locality 36).

	Ft.	in.
Shale.		
Coal		5½
"Sulphur"		1
Coal	1	2
Bone		2
Coal	1	5½
Clay shale.		
Thickness of coal bed	3	4

Roadside exposure in south-central part of sec. 29 (locality 35).

	Ft.	in.
Shale, sandy.		
Coal, shaly		9
Clay	1	
Coal	2	6
Clay shale.		

A sample of the core in the Wiley Carter mine, half a mile south of Mount Ephraim (locality 37), was taken for analysis (No. 20235, p. 40). A section of the coal in this mine is given in Plate VI.

The thickness of the bed at the extreme southeast corner of the township is indicated by a measurement made on the J. S. Sparling farm, across the township line, 1 mile east of Whigville (locality 42), where the bed from top to bottom shows coal, 2 feet 3 inches; shaly coal, 5 inches; and coal, 1 foot 10 inches; total thickness, 4 feet 6 inches.

From the above sections it is evident that the bed is of less value in Seneca Township than to the south, the thickness being only a little more than 3 feet in most places. The bed is, however, of good quality and ample in quantity for the needs of the farmers.

SANDSTONE AND LIMESTONE.

One bed of sandstone suitable for buildings and foundations is found in this township. It lies between the Lower Pittsburgh limestone and Meigs Creek coal. This rock, with associated beds, forms the conspicuous terrace about 150 feet above the valley in the western part of the township. The outcrop of the sandstone remains wooded because the slopes are too steep and rocky for cultivation. The sandstone has been quarried at a few places northeast of Riches School, in secs. 20, 29, and 30. The beds are in layers 2 to 4 feet thick in convenient attitude for quarrying. Similar exposures are found in the valleys at the south side of the township. In the northeastern part the beds are shaly and less massive.

The important limestone beds of this township are three in number and occupy positions 30, 90, and 125 feet below the Meigs Creek coal. The Lower Pittsburgh limestone, the lowest of the three, is 2 to 3 feet thick in all but the western part of the township, where

it is nodular and less conspicuous than the Upper Pittsburgh limestone, about 25 feet higher. The limestones beneath the Pomeroy coal and the Fishpot limestone (beneath the Lower Meigs Creek coal) are persistently 1½ to 3 feet thick.

These limestone beds are so widely distributed through the township that they offer a ready supply of material for surfacing the roads. Nevertheless no limestone pikes have been built in this township, and only a few miles of pike in adjoining ones.

CENTER TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Center Township occupies the southwestern part of the Summerfield quadrangle and narrow areas along the borders of adjacent quadrangles. The eastern part of the township lies within T. 7 N., R. 8 W., as designated by the original land survey, and the western part includes two north-south rows of sections within T. 7 N., R. 9 W. Sarahsville, the only village, is in the north-central portion on the Ohio River & Western Railroad, about 6 miles northeast of Caldwell, the county seat. The number of inhabitants in Sarahsville, according to the census of 1920, was 186, and in the entire township 1,083. The mineral resources include a coal bed in the hills of the eastern half of the township, possibly some minable coal below the surface, and three small oil pools.

Nearly all of Center Township is drained by Buffalo Creek, which flows northwestward and unites with Wills Creek at Hartford. A small area in the southwestern part is drained by branches of Duck Creek. The valley of Buffalo Creek widens into bottom lands of unusual extent a few miles from its source. Along the valley are low benches 30 to 40 feet above stream level, the tops of which are formed of a layer of sandy silt. These benches with their deposits are remnants of a former valley floor that has been largely worn away in the deepening of the valley to the modern flood plain. From them the slopes rise in terraces of moderate steepness to the summits of the ridges, which are 300 to 400 feet above the valley floor, or 1,150 to 1,250 feet above sea level. Terraced slopes are developed to an unusual degree in the northwestern part of the township, and their undulating profiles add to the beauty of the landscape. They are caused by rocks of varying resistance to weathering, such as tough shaly sandstone alternating with beds of clay, shale, and limestone. The resistant sandy beds are effective in retarding the tendency to "creep" of the softer beds, but landslides are fairly prevalent on slopes that have been without timber for a number of years.

GEOLOGIC SECTION.

The general direction of dip of the rocks in Center Township is southeast at an average rate of about 25 feet to the mile; therefore strata that lie low in the hills at the east side of the township rise westward to much higher positions and may be lacking even in the ridge tops. In like manner strata that crop out on Buffalo Creek at the northwest corner of the township lie far below the bottoms of the deepest valleys at the southeast corner. The thickness of beds thus exposed is in columnar section about 500 feet. Their stratigraphic sequence is illustrated by figure 2 (p. 16). The Conemaugh beds, constituting the lower part of the section, consist largely of sandy shale of light olive brownish-gray color, interbedded with reddish-brown shale and clay containing nodules of limestone and hematite. The few coal beds are thin and nonpersistent. Beds of limestone are likewise few and inconspicuous, with the exception of the Ames and Lower Pittsburgh. The Ames limestone is a brownish-gray impure rock stained with iron rust and containing abundent remains of fossil shells. This limestone, together with nonpersistent beds 15 to 60 feet higher, also fossiliferous, records the last invasion of the ocean into this region in "Coal Measures" time, and higher beds carry no fossil forms of known marine types.

The strata of the Monongahela formation differ from those below in that they lack the reddish-brown color and contain several beds of coal and of gray limestone. The coal beds, except the Meigs Creek, are thin or absent in Noble County, but to the northeast in Belmont County they are of great importance.

The principal hillside terraces in Center Township occur above the Ames limestone, above the Lower Pittsburgh limestone, and a little below the Meigs Creek coal. The lowest one appears along Buffalo Creek downstream from Sarahsville. It is controlled by sandy shale of pale greenish-yellow color. At the base are numerous springs which are led to the surface by clay associated with the Ames limestone.

Above the Ames terrace is a long, gentle rise to the level of sandy beds about 190 feet higher which overlie the Lower Pittsburgh limestone and form the terrace so conspicuous west and north of Sarahsville at an elevation of 1,000 to 1,050 feet above sea level. Still higher clay and limestone beds alternating with sandstone and sandy shale form other terraces that are only slightly less prominent.

STRUCTURE.

The prevailing dip or slope of the strata, as shown by elevations of the Meigs Creek coal and other beds determined by spirit leveling, is southeast, at 10 to 50 feet to the mile. No well-marked anticlines

or synclines are present, but there are minor flexures which cause considerable local variation in the direction of dip and form anticlinal "noses" and synclinal "embayments" such as those in the vicinity of Mount Ephraim Station shown on the structural map (Pl. XII, in pocket).

MINERAL RESOURCES.

COAL.

MEIGS CREEK COAL.

The Meigs Creek is the only important coal bed that crops out in Center Township. In the western half of the township it lies in the tops of the highest hills, where the cover is so slight that the coal is of little value. Eastward from a north-south line passing through Sarahsville there are so many small mines that it is safe to conclude that the bed is everywhere 4 feet or more in thickness. There is commonly a layer of clay a little above the middle dividing the coal into two benches. The rock overlying the coal is sandy shale or sandstone.

Sections of Meigs Creek coal bed in Center Township.

Mine on J. H. Young farm, 1 mile east of Sarahsville (locality 39).

	Ft.	In.
Sandstone.		
Coal	2	6
Clay		9
Coal	1	9
Shale		1
Coal	1	5
Clay shale.		
Thickness of bed	6	6

Mine on C. Hague farm, half a mile east of Fredericksdale (locality 40).

	Ft.	In.
Clay shale.		
Coal	1	1
Clay	1	
Coal	4	
Clay shale.		

Mine on H. Carter farm, sec. 8, 2 miles northeast of Sarahsville (locality 38).

	Ft.	In.
Clay, carbonaceous		1
Clay, gray		6
Coal, with irregular bony bands	3	4
Clay, unmeasured.		

Where seen in openings in the vicinity of Mount Ephraim Station the bed is a few inches less than 4 feet thick and is overlain by shale, which in turn is overlain by a thick bed of sandstone. In the southeast corner of the township, near East Union, the coal is divided into two benches by the usual clay bed. The upper bench, which is 1 to 2 feet thick, is seldom used and is left up in the rooms as a roof. The lower bench ranges from 3½ to a little more than 4 feet in thickness.

COAL BEDS BELOW THE SURFACE.

The Upper Freeport coal mined at Senecaville and near Caldwell is about 570 feet below the Meigs Creek coal. In the valley of Buffalo Creek at the northwest corner of the township it is about 180 feet below the surface. Several coal test holes have been drilled in the valley, but the results are not available. A coal that is possibly the Upper Freeport is reported in the logs of some of the wells drilled for oil between Sarahsville and Caldwell.

SANDSTONE AND LIMESTONE.

The principal sandstone bed of Center Township lies about 60 feet below the Meigs Creek coal bed. It ranges from tough shaly beds to moderately massive layers that are well suited for building. The rock has been quarried by the farmers in a small way in the northeastern part of the township.

A sandstone bed overlies the Meigs Creek coal along much of its outcrop. The rock is of little use on account of its soft, friable texture. At one place east of Sarahsville it has been pulverized and used for building sand.

The principal limestone bed of Center Township is the Lower Pittsburgh, which lies about 145 feet below the Meigs Creek coal at the base of the prominent terraces in the western part of the township. This limestone is persistently 3 to 4 feet thick in all but the northern part of the township and is exposed in conspicuous outcrops along the hillsides. Where measured in the railroad cut 1½ miles south of Sarahsville the beds are 3½ feet thick. (See Pl. II, p. 16.) The weathered surface is invariably lumpy, and the rock is a limestone conglomerate. It is so firmly cemented that when broken the fracture passes indiscriminately through the pebbles as well as the matrix. The rock is well suited for various purposes, the most important being for road metal.

From 43 to 50 feet above the Lower Pittsburgh limestone is another dark bluish-gray laminated limestone about 2 feet thick. About 60 feet higher, or 20 feet below the Meigs Creek coal, is a gray resistant limestone 2 to 3 feet thick, the Fishpot, which is probably second in abundance to the Lower Pittsburgh. The total supply of limestone easily available in Center Township is ample for the building of many miles of good pike, but little work of that kind has been done.

The Ames limestone is of little or no value because of its slight thickness in Center Township. In typical exposure it is a single layer of brownish color, 1 foot or less thick. In the southern part of the township it consists of many thin beds of shaly limestone and calcareous shale 10 to 15 feet thick.

MARION TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Marion Township occupies an area of about 24 square miles in the south-central part of the Summerfield quadrangle. It includes the villages of Summerfield and Whigville, on the Ohio River & Western Railroad. The township is one of the richest in mineral resources in Noble County. The population, as given in the Census report for 1920, was 1,246 people, 484 of whom lived in Summerfield.

The township, with its present boundaries, is made up of parts of three townships of the early system of surveys, and for this reason some section numbers are used twice in different parts of the township. In the two eastern tiers the sections are numbered from south to north and in the remaining portion from east to west and then back and forth, beginning with the northeast corner of the township, according to the system now in use by the General Land Office.

Marion Township consists of a highland greatly dissected by deep ravines that have their sources on the principal divides in the central portion, separating northward-flowing branches of Wills Creek from the southward-flowing waters of Duck Creek. The elevations on this principal divide and its lateral extensions range between 1,150 and 1,250 feet above sea level. The lowest valley in the southern part of the township is that of East Fork of Duck Creek, about 780 feet in elevation, and the lowest in the northern part is that of Seneca Fork of Wills Creek, about 840 feet in elevation. The valleys of Seneca Fork and its tributaries are markedly broad. The Seneca Fork Valley, with its marshy bottomlands nearly half a mile wide, is occupied by a sluggish stream that follows a meandering course among numerous abandoned oxbows and sloughs. The slight fall, less than 5 feet to the mile, makes the run-off so slow that floods are common.

GEOLOGIC SECTION.

The Meigs Creek coal is the one coal bed that appears in minable thickness in Marion Township. It has been so extensively mined by the farmers that almost every farm is scarred with one or more prospect pits. In opening a mine the entrance is seldom securely timbered, and as a result it falls sooner or later, after coal has been extracted for a few seasons. Frequently, therefore, one may see from any good point of view on a hill a number of abandoned mine dumps with their car tracks and posts at the mine entrance.

The strata overlying the Meigs Creek coal consist of either shale and sandstone or clay and limestone, the latter being most prevalent in the eastern part of the township. There is commonly a bed of olive-

green clay about 14 feet above the coal. The character of the beds above and below the Meigs Creek coal, as seen near the railroad 1 mile northwest of Summerfield, is illustrated by the following section:

Section of beds at horizon of Meigs Creek coal near railroad 1 mile northwest of Summerfield.

	Feet.
Limestone, white, in several beds, unmeasured.	
Clay shale, olive-green	4
Limestone and clay shale	10
Coal, Meigs Creek	5±
Sandstone and sandy shale, unmeasured.	

About 120 feet above the Meigs Creek is another coal, the Uniontown, which appears as a blossom at numerous points on the ridges. Where seen in fresh exposures in railroad cuts and ravines it consists largely of bony coal with black shale. The strata above it are either sandy shale or thin-bedded sandstone about 50 feet thick, at the top of which is a bed of green clay and a few feet higher a coal blossom which marks the position of the Waynesburg coal, a bed of considerable value to the east, in Belmont County. (See Pl. IV, *B*, p. 18.)

The strata below the Meigs Creek coal consist of several limestone beds alternating with sandy shale and clay, with faint "markers" of coal beds that are of importance in other townships.

A record of strata penetrated in well No. 544 drilled on the F. L. Craig farm, half a mile south of Steamtown, is given below. This record, although incomplete, is of interest because it shows the positions of the principal sands with reference to the Meigs Creek coal and the names applied to them by oil men.

Log of well No. 544 on F. L. Craig farm.

	Thickness.	Depth.
	Feet.	*Feet.*
Coal, Meigs Creek		75
Rock, red	100	240- 340
Sand, 80-foot	60	340- 400
Rock, pale red	45	400- 445
Sand, 140-foot	60	445- 505
Sand, 300-foot	100	595- 695
Sand, 500-foot	14	812- 826
Sand, Stray	25	875- 900
Sand, Schramm	23	945- 968
Lime, Big	17	1,063-1,080
Sand, Keener	15	1,165-1,180
Sand, Big Injun	183	1,188-1,371
Sand, Berea; gas at 1,742-1,750 feet	9	1,741-1,750

STRUCTURE.

The dip of the strata in Marion Township varies considerably both in direction and degree. In general it is southeastward at a rate ranging from a few feet to 50 feet to the mile. In the northwest corner of the township the rocks lie nearly flat in an area of more than a square mile, and to the southeast in the succeeding half mile they

dip 40 feet. At the east side of the township north of Summerfield the rocks dip gently westward from the crest of a small anticlinal fold near the township line.

The structural map (Pl. XII, in pocket) is constructed from elevations determined on the Meigs Creek coal, and therefore the direction and degree of dip of that bed at any point can readily be ascertained by an inspection of the map. In opening coal mines it is desirable that the site for the entry be selected on a hillside where the rocks dip toward the mine entrance, in order that the water may drain from the mine workings and that the coal may be delivered at the mine mouth by gravity. The structural map will therefore be useful in the selection of locations for mines.

MINERAL RESOURCES.

The principal mineral products of Marion Township are coal, oil, and gas. The Summerfield gas field, one of the most valuable ever discovered in which the gas is obtained from the Berea sand, lies within the township. In the southern part of the township small quantities of oil are derived from the 500-foot sand and also the Berea sand.

COAL.

BEDS THAT CROP OUT.

The Meigs Creek coal is the only coal bed of minable thickness included in strata that crop out in Marion Township. The Uniontown coal bed, 115 to 140 feet above the Meigs Creek, forms a conspicuous blossom at a few places, but the coal is so shaly and bony as to be of little use. Its thickness where exposed in the railroad cut at Whigville (Pl. IV, *B*) is as follows:

Section of Uniontown coal bed at Whigville.

	Ft.	in.
Shale, sandy.		
Coal		6
Clay		2½
Coal	1	
Clay shale	1	6
Shale, bony	2	6
Coal		8
Shale, unmeasured.		

The extent of the Meigs Creek coal is shown on Plate VI, and its importance as a local source of fuel is evident from the numerous mines. The bed was formerly mined near Steamtown for railroad shipment, but the workings have been abandoned. In an area about ½ mile in width along the east side of the township the coal bed is little more than 2 feet thick. This is probably its thickness on the hills on the east side of Glady Run north of Summerfield and also

along the railroad southeast of the village. To the west the bed is believed to be uniformly 4 feet or more thick.

Sections of Meigs Creek coal bed in Marion Township.

Van Dyne Bros. mine, on J. S. Sparling farm, 1 mile east of Whigville (locality 42).

	Ft.	in.
Shale, unmeasured.		
Shale, black		10
Coal	2	3
Coal, bony with "sulphur"		5
Coal	1	10
Clay shale.		
Thickness of coal bed	4	6

T. C. Hague mine, southwest of railroad at Steamtown (locality 44).

	Ft.	in.
Clay shale.		
Coal		5
Clay	1	1
Bone		2
Coal	3	3
Clay		1½
Coal	1	3½
Clay shale.		
Thickness of coal bed	4	10

Where measured on Lexington Ridge at the south township line the bed is 4 feet 9 inches thick and contains no clay partings. A mile farther west, on the King farm, in the SE. ¼ sec. 23 (locality 45), the bed shows a thickness of 5 feet, with 1 foot of clay above and 1 foot of roof coal. At the northwest corner of the township the bed is as a rule 4 feet thick and is overlain by black shale with or without a layer of roof coal.

COAL BEDS BELOW THE SURFACE.

One or more coal beds are recorded in a number of wells drilled for oil and gas in Marion Township. The positions of the beds range from 300 to 800 feet below the Meigs Creek coal. There is little reliable evidence as to the thickness of these beds, and their identification is difficult owing to their seeming lack of agreement as to position with reference to the Meigs Creek coal. The Upper Freeport coal, which is mined at Senecaville and near Caldwell, if present n Marion Township, probably lies about 560 feet below the Meigs Creek coal.

LIMESTONE AND SANDSTONE.

The limestone beds of Marion Township, although not of great thickness, are so distributed as to furnish a ready source of material for road building throughout the township. A pike leading north from Summerfield along the ridge toward Batesville is the only road that has been improved in this or adjoining townships.

One of the most useful limestone members is the Lower Pittsburgh, which is persistently about 3 feet thick. It lies 50 to 100 feet above the valleys in the northern part of the township, and its white beds form a conspicuous outcrop on the hillsides. The same limestone is also seen along East Fork of Duck Creek and its tributaries in the western part of the township. Other limestone beds are found about 30 feet below the Meigs Creek coal and also above it, some of which are suitable for road metal.

Sandstone in thick beds suitable for quarrying operations is not plentiful in Marion Township. The most promising exposures occur in the western part of the township, where beds lying about 50 feet below the Meigs Creek coal form a prominent terrace, with local outcrops of massive character.

ENOCH TOWNSHIP.

A narrow strip along the north margin of Enoch Township is included in the Summerfield quadrangle. Fulda, the only village in the township, lies on a ridge 1½ miles to the south, in the Macksburg quadrangle. The portion of the area here described is probably best known on account of the Salt Run and Low Gap oil pools, in which the oil is derived from the Buell Run sand.

The Meigs Creek coal lies well up in the ridges at elevations ranging from 1,050 to 1,080 feet above sea level, or 100 feet above the valley of Buffalo Creek at the north edge of the township. It is present in minable amount throughout the township, and the thickness ranges from 5 to 7 feet or more. The value of the bed is somewhat lessened by a clay layer near the middle, which is commonly 1 foot thick. The character of the coal bed is illustrated by the following section:

Section of Meigs Creek coal bed in Lawrence Schaffer mine, near Fulda.

	Ft.	in.
Shale and sandstone.		
Coal	2	6
Clay		10
Coal	4	
Clay.		
Thickness of bed	7	4

In Enoch Township the Meigs Creek coal is overlain by sandstone or sandy shale instead of limestone, agreeing in this respect with rocks in townships to the east.

STOCK TOWNSHIP.

LOCATION AND SURFACE FEATURES.

The north end of Stock Township is included within the Summerfield quadrangle. It is drained by East Fork of Duck Creek and its tributaries, which follow in general a southeasterly direction. East

Union and Carlisle, situated in the valley, are the only villages. The number of inhabitants in the township, according to the census report of 1920, was 934, of whom 105 lived in Carlisle.

The surface is moderately rugged, and the valleys are narrower and bounded by steeper slopes than those of most valleys in the county, especially those to the north and west, in Seneca and Center townships. The valley of Duck Creek lies 720 to 770 feet above sea level in this township and is bordered by ridges whose summits are about 400 feet higher. The highest ridges are slightly more than 1,200 feet above sea level.

GEOLOGIC SECTION.

The most conspicuous bed in the township is the Meigs Creek coal which is mined in all but the eastern part of the township. Its elevation in the vicinity of East Union ranges from 1,026 to 1,04[illegible] feet above sea level, or about 270 feet above the village. The coal dips gently to the southeast, and at the south edge of the quadrangle where mined in the hill west of Duck Creek, it lies 992 feet above sea level.

The beds above the Meigs Creek coal consist of either clay and limestone or sandstone. The sandstone is most prevalent. About 15 feet above the coal is locally a bed of olive-green clay, which is so peculiar in appearance that it can not be mistaken for any other bed in the region. The only trace of coal in rocks above the Meigs Creek coal bed is about 138 feet higher, at the horizon of the Uniontown which is marked by 1 foot or so of bony coal or black shale. The higher strata consist largely of sandstone and sandy shale with a few clay beds.

The succession of strata usually found below the Meigs Creek coal is shown below.

Section of strata below Meigs Creek coal, in Stock Township.

	Feet.
Coal, Meigs Creek	2–4
Shale of sandstone	28
Limestone, with coal marker above	3
Shale, sandy, with one or more beds of clay or limestone	48
Limestone, dark, shaly	2
Shale, sandy	27
Clay, calcareous, with coal marker above at place of Pittsburgh coal	2
Shale	19
Limestone, Lower Pittsburgh beds	4
Clay and shale, greenish gray to brownish red, with sandstone beds; thickness to bottom of valley	100±

The Lower Pittsburgh limestone probably ranks second to the Meigs Creek coal in its prominence as an easily recognized stratum

The gray boulders form conspicuous outcrops on the hillsides and at waterfalls in the ravines. There are higher beds only slightly less prominent, and the township is therefore supplied with an abundance of easily accessible limestone material for surfacing its roads. There are, however, no pikes, and little attempt has been made to improve the roads.

COAL BEDS.

The only coal bed of economic importance in Stock Township is the Meigs Creek. It has been mined by the farmers at dozens of places and maintains a thickness of 4 to 5 feet throughout the township except in a strip at the east side less than 2 miles wide, where it thins to about 2 feet. The thickness in a hollow at the north edge of sec. 28 (locality 49), and also half a mile farther north, in a valley east of Curtis Church, is about 2 feet. On the hillside a few hundred feet west of the church, in sec. 35 (locality 48) the bed is a little less than 2 feet thick.

Half a mile to the west the bed is several feet thick and locally consists of two benches, each of which is minable, separated by a few inches to a foot or more of bony coal or clay. A measurement at the mine on the Martha Curtis farm, in sec. 25 (locality 46), shows that the bed is without partings and is 4 feet 9 inches thick. In sec. 3 the bed is much broken by partings, as shown in the following section:

Section of Meigs Creek coal bed at mine on J. H. Bates farm, NW. ¼ sec. 3, 2 miles west of Carlisle, about one-quarter mile south of Summerfield quadrangle.

	Ft.	In.
Sandstone.		
Coal		11
Bone.		
Clay		8
Coal	1	1
"Soot"		¼
Coal	2	1
Bone		¼
Coal	1	10
Clay.		
Thickness of bed	5	[illegible]½

BEAVER TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Beaver Township occupies all but a narrow strip at the west side of T. 8 N., R. 7 W., as designated in the original land survey. Batesville, the only village, is near the center, about 3½ miles from the Baltimore & Ohio Railroad, which touches the northeast corner. The population of the township in 1920 was 1,190. The land is fairly fertil-

and tobacco is the principal crop. Coal is the most important mineral product. The northeast corner of the township is underlain by the Pittsburgh bed in minable thickness, and the northwest half by the Meigs Creek bed.

Beaver Creek, flowing westward through the central portion, is the principal drainage line and is joined by a number of parallel tributaries from the north. Those from the south are few and small. This unsymmetrical arrangement of drainage lines is true not only of Beaver Creek, but also of many other east or west flowing streams in this region, which have a number of long tributaries from the north and only a few short ones from the south. Less than 1 mile south of Beaver Creek is a divide separating its waters from these of southward-flowing branches of Seneca Fork of Wills Creek.

The valleys are bordered by fairly steep hills, whose summits are 1,200 to 1,300 feet above sea level. They are considerably higher than those to the west, in Wayne Township, and the surface is on the whole more rugged than that of townships on the west and east.

GEOLOGIC SECTION.

The principal members of the geologic section in the northeastern part of the township are the Pittsburgh coal bed in minable thickness and a prominent sandstone about 70 feet higher, at the base of which is the Lower Meigs Creek coal bed, 1 to 2 feet thick. The Meigs Creek coal is missing in this vicinity, but its position is near the top of this sandstone, or about 35 feet above the Lower Meigs Creek coal. When followed in a southwesterly direction the sandstone gives place to sandy shale and the Meigs Creek coal assumes a minable thickness. In the same vicinity the Pittsburgh coal abruptly thins to a mere blossom, and where geologically due farther southwest it is missing altogether.

The Pittsburgh coal thins southwestward from a bed 4 feet thick to a carbonaceous streak, within less than 1 mile. The overlying and underlying strata are much the same where the coal is present and where it is lacking, and there is seemingly little evidence as to the cause of the change. The principal difference is a thickening of the underlying limestone beds in the barren area. There may have been a deepening of the great swamp in Pittsburgh time which resulted in the formation of a great open lake that afforded favorable conditions to the accumulation of thick limy muds but not for the uninterrupted acccumulation of plant materials into peat beds.

The irregularity of the Meigs Creek coal bed is obviously to be ascribed to a different cause. The formation of a peat bed of uniform thickness at that time was hindered and locally prevented by the contemporaneous deposition of quantities of sand, possibly at the deltas of several rivers.

The succession of strata below the surface is illustrated by the following well record:

Log of well No. 96 on Roe farm, in the NW. ¼ sec. 19, Beaver Township.

[Well head 100 feet below Meigs Creek coal.]

	Thickness.	Depth.
	Feet.	*Feet.*
Surface	10	10
Limestone		20
Rock, red		124
Shale, sandy	21	124-145
Rock, red	35	145-180
Coal, Brush Creek (?)	4	400
Coal, Upper Freeport (?)	4	470
Sand, salt (gas)		560
Sand, Keener (oil)	5	903

STRUCTURE.

The general southeastward dip in this region is varied in Beaver Township by several minor flexures, which produce considerable variation in the direction of dip. At the west side of the township is a shallow synclinal embayment extending northward from Summerfield. To the east this is paralleled by an anticlinal nose extending southward from Quaker City. The direction of dip therefore varies from east or southeast to south, southwest, and even west. The dip is at most 40 or 50 feet to the mile, and locally as little as 10 feet.

MINERAL RESOURCES.

Oil and gas have long been produced from the Temperanceville pool, a portion of which extends into Beaver Township. The productive oil sand here, as well as in the Barnesville pool, to the north, is the Berea. A small amount of oil has been obtained from the Keener sand 2½ miles southwest of Batesville. Coal, limestone, and sandstone are also important mineral products in the township.

COAL.

Of the coal beds that crop out in this township, the Pittsburgh, Lower Meigs Creek, and Meigs Creek are the only ones of sufficient value to be worthy of description. Other coals far below the surface have been recorded in a few oil wells, but the information available is meager. A bed, probably the Upper Freeport, is found in wells drilled on the Roe farm, in sec. 19, as shown in the record above.

PITTSBURGH COAL.

The Pittsburgh coal bed crops out in minable thickness in only a few square miles in the northeast corner of the township. (See Pl. V, p. 28.) The limiting line extends roughly from Temperan-

ville northwestward toward a point half a mile south of Quaker City. Southwest of this line the Pittsburgh coal is represented by a marker of black shale resting on the Upper Pittsburgh limestone.

Half a mile west of Temperanceville, on the C. E. Wilson farm, at the south line of sec. 4 (locality 11), the coal as indicated by a ravine exposure is only a few inches thick. The following section was measured at this point:

Section showing strata at horizon of Pittsburgh coal on C. E. Wilson farm.

	Feet.
Coal blossom, Pittsburgh, thin.	
Limestone, bluish gray, weathering to light gray with yellowish mottlings	5
Clay shale	20
Limestone, gray, with ocherous yellow patches and brecciated structure	4

Along the valley in the N. ½ sec. 4 are small mines from which th Pittsburgh coal has been taken, and the thickness of the bed is abou 4 feet. Several openings have been made on the Douglass farm, a the north side of sec. 10, and farther north up the valley. The coa is reported to be thin in the ravine west of the crossroads, but to b 3 to 4 feet thick about 600 feet farther north. It is reported tha coal 3 feet thick was once dug from the creek bed at the east sid of sec. 17 (locality 5). A good thickness is found at the head of th valley at the southeast corner of sec. 12, where the bed has bee mined on the Flood farm. To the west, along the south side o sec. 12 and across the border of sec. 18, there is some uncertaint whether the bed is of minable thickness. The same is true in th NW. ¼ sec. 18. In sec. 6 near the railroad and to the south alon the township line the bed is about 4 feet thick and is overlain b sandstone which in places forms an undulating contact with th coal. The sandstone masses extending down into the coal are calle "rolls" or "horses" by the miners.

LOWER MEIGS CREEK COAL.

The Lower Meigs Creek coal is persistent throughout large area in thicknesses of 1 foot or less. Locally it thickens to 2 feet and ha been stripped for home use at a few places. Its position is 75 to 8 feet above the Pittsburgh coal and 30 to 40 feet below the Meig Creek. In sec. 11, near Tuckyho School, the bed is slightly mo than 2 feet thick. Where seen at numerous places in the hills sout east of Batesville the thickness ranges from 1 foot 2 inches to 1 fo 7 inches, but toward the west it decreases to less than 1 foot.

MEIGS CREEK COAL.

The Meigs Creek coal bed in minable thickness is limited to th northwest half of Beaver Township. The line marking the limit minable coal extends approximately along the road leading fro

Summerfield to Batesville, thence east 1 mile, north through the center of secs. 10 and 11, and northwest toward Quaker City. East of this line the bed is generally less than 1 foot 6 inches thick and in places is a mere carbonaceous streak. West of the line the thickness increases to about 4 feet. "Clay veins" and "horses" that give considerable trouble in mining are common.

North of Beaver Creek a number of measurements were made, as follows:

At the C. W. Long mine, in sec. 30 (locality 55), the bed has a thickness of 4 feet 5 inches, at a roadside exposure in the SE. ¼ sec. 24 (locality 56) it is 4 feet 3 inches thick, and at a roadside exposure in the S. ½ sec. 18 (locality 57) it is 3 feet 3 inches thick.

A section of the G. W. Griffin mine, in sec. 11 (locality 61), is given on Plate VI (p. 32) and also on page 46. A sample for analysis was taken in this mine (analysis 20185, p. 40).

Where seen in a slip at the top of a hill half a mile east of Batesville (locality 60) the coal is about 3 feet thick. In the hills west of Batesville its thickness is in most places about 4 feet. In a few places there is an upper layer of coal separated from the main bed by a foot or so of clay.

About 1 mile east of Palestine Church, in the NW. ¼ sec. 14 (locality 59), the coal, where exposed at the forks of the road, is 1 foot 3 inches thick. The Lower Meigs Creek coal, with a thickness of nearly 2 feet, appears along the road 28 feet lower, underlain by limestone. Half a mile to the west, in sec. 20, the Meigs Creek coal is 2 to 3 feet thick, and farther west it thickens to about 4 feet. Over the coal is a massive bed of coarse-grained sandstone.

Section of Meigs Creek coal in Joseph Morris mine in the SW. ¼ sec. 26, Beaver Township (locality 58).

	Ft.	in.
Shale.		
Coal, impure		10
Shale, soft	1	2
Coal	1	8
Shale		2
Coal		10
Clay and "sulphur"		1
Coal	2	½
Clay shale.		
Thickness of lower bench	4	9½

At the center of sec. 19 there is a faint blossom of the Meigs Creek coal, and it is a safe conclusion that the coal is not present in minable thickness in this vicinity. Exposures seen in the hills to the west across the valley indicate a thickness of 3 to 4 feet.

UNIONTOWN AND WAYNESBURG COAL BEDS.

The Uniontown and Waynesburg coals are present in the highest ridges in the southeastern part of the township. So far as known, the Uniontown is no thicker than 1 foot at any point. It was seen at a number of places on the ridge north of Calais. The Waynesburg coal is reported to be almost 2 feet thick near the east township line in sec. 2, where at one time it was mined for use on the Carpenter farm.

LIMESTONE AND SANDSTONE.

Beaver Township probably has a greater quantity of limestone in easily accessible outcrops than any other township in this region. A fair limestone pike has been built the greater part of the distance from Summerfield through Batesville to Quaker City, but aside from this almost no use has been made of the limestone. Most of the roads are poor, especially those along the valleys, which become almost impassable in rainy weather.

The positions of the principal beds are evident on any hillside, owing to the prominent outcropping white layers that are freshly exposed each year through the slipping of the loose soil cover. The Lower Pittsburgh and Upper Pittsburgh limestones are the most conspicuous. Their positions, together with those of other beds, are illustrated by the following section measured along the road at the south side of sec. 9:

Section showing limestone beds in sec. 9, Beaver Township.

	Feet.
Coal blossom, Lower Meigs Creek.	
Limestone, Fishpot, gray; weathers to chalky white	2
Shale, sandy; forms steep slopes	50
Limestone, dark blue, laminated	2
Shale, sandy	30
Limestone, Upper Pittsburgh, gray	3
Shale, sandy	24
Limestone, Lower Pittsburgh, in several layers forming waterfalls in ravine	7

The Fishpot limestone is possibly of sufficient purity to be burned for building lime. Other beds, although somewhat ferruginous, are burned by the farmers for agricultural lime.

Coarse sandstone in thick layers occurs below the Meigs Creek coal in the eastern part of the township. It is conspicuous north and south of Temperanceville, where its great blocks are distributed along the hillsides and cliffs, and are conspicuous in the ravines. A similar sandstone is present above the Meigs Creek coal in a small area in the northwestern part of the township.

The sandstone in the vicinity of Temperanceville and northward is rusty brown or yellowish gray in color and of coarse texture. It has

been used principally for foundations and bridges, but will probably be found of some value for building. Like most other beds of the region, however, it is soft and loosely cemented and therefore does not resist weathering to the extent desired.

BELMONT COUNTY.

The portion of Belmont County included in the Woodsfield quadrangle is the southwest corner, comprising Wayne and Somerset townships and parts of Warren, Goshen, Smith, and Washington townships. All these townships are regular in shape and the sections 1 mile square, into which they are divided, are numbered in north-south rows, beginning at the southeast corner, as was customary in the earliest surveys of this region.

WARREN TOWNSHIP.

SURFACE FEATURES.

Warren Township, the southern half of which is included in the Woodsfield quadrangle, has a greater population than any other township in the area here described, the census of 1920 showing a total of 6,770. Barnesville, a town of 4,865 inhabitants, lies in the south-central portion, on the Baltimore & Ohio Railroad, which follows a northeastward route across the township. The principal divide of the area, separating eastward-flowing tributaries of Ohio River from branches of Tuscarawas River, extends in a north-south direction, and on it the hilltops range from 1,250 to 1,350 feet in elevation. The least elevation is about 900 feet on Leatherwood Creek at the southwest corner of the township. At this point the railroad track is about 1,025 feet above sea level, and in the distance of about 4 miles to Barnesville it climbs to about 1,240 feet, giving a difficult grade up which heavily loaded trains must be helped by a second engine.

The surface is least rugged in the eastern part of the township, where there is considerable rolling upland that is broken only by shallow valleys occupied by the headwaters of Captina Creek and its tributary Long Run. This portion is best suited to farming both on account of its gentle topography and also for the reason that the soil is enriched by the decomposition of many limestone beds. The western portion has a more rugged surface, being cut by many deep ravines with steep slopes.

GEOLOGIC SECTION.

The rocks that crop out in Warren Township have a thickness of about 400 feet and include in ascending order the upper portion of the Conemaugh formation, all of the Monongahela, and about 100

feet of the Washington. The rocks of the Conemaugh formation, as shown by the geologic map, crop out only along Leatherwood Creek and its branches and in the valley in sec. 33. The ridges between these valleys and all the upland to the east consist of strata in the Monongahela and Washington formations. The stratigraphic sequence is illustrated by the following section, which is a generalization of observations made throughout the township:

Generalized section in descending order of strata outcropping in Warren Township.

	Feet.
Washington formation:	
Sandstone, coarse-grained, friable, capping the ridges east and south from Barnesville, correlated with Mannington sandstone of West Virginia Geological Survey	40
Coal, Waynesburg "A," commonly in two parts, separated by 4 to 8 feet of shale. Both beds thin.	
Shale or shaly sandstone	45
Monongahela formation:	
Coal, Waynesburg; too thin to be of value in Warren Township.	
Shale or shaly sandstone	48
Coal, thin, Uniontown.	
Shale	7
Limestone, dark, nodular, containing minute fossils	1
Shale, sandy	20
Limestone, Benwood, in many beds interlain with clay shale. In the northwest half of the township the limestone is missing, and in its place is sandy shale or sandstone	68
Coal, Meigs Creek; of workable thickness in nearly all of township	4
Sandstone or sandy shale	18–30
Coal, Lower Meigs Creek; of variable thickness; contains shale and "sulphur" bands	1–3
Limestone, Fishpot, in one or more layers	1–3
Shale and sandstone with one or more beds of limestone	60–75
Coal, Pittsburgh; workable throughout the township; mined at Baileys Mills	4
Conemaugh formation:	
Clay and limestone	4
Shale, sandy	19
Limestone, Lower Pittsburgh, grayish, with rusty-brown spots	3
Shale and sandstone and beds of reddish-brown clay	75

Of the strata represented in the above section probably the best known are the coals, especially the Pittsburgh and Meigs Creek. The Pittsburgh coal is mined for railroad shipment by two companies at Baileys Mills. Thence northeastward along the valley toward Barnesville the roadside is bordered by dozens of old openings. ...s in the Meigs Creek coal, which is about 100 feet higher ...sburgh, are fewer, and at present only one mine is in ...ion on Leatherwood Creek. The sandstone, so promi... ...s 2 miles west of Barnesville, locally occupies the posi... ...eigs Creek coal and associated strata.

Good exposures are not plentiful in the eastern part of the township, where the gentle slopes have a covering of soil that obscures outcrops. Much of the section is washed bare along the roadsides, and most of the geologic evidence available is obtained in such places. The Meigs Creek coal lies in the bottom of the valley of North Fork of Captina Creek; this coal and a thick sandstone, probably the Mannington sandstone of West Virginia reports, which caps the ridges, are the most noteworthy strata. The knowledge concerning the rocks below the surface is obtained from records of oil wells. The position of the Upper Freeport coal, which is mined near Lore City and other points to the west, is about 440 feet below the Pittsburgh coal. Its presence in Warren Township has not been proved.

STRUCTURE.

The direction and amount of inclination of the rock beds in Warren Township are expressed on the map by means of contours representing the "lay" of the Pittsburgh coal. The general dip is southeast, with local variations. West of Barnesville is a low fold trending northeast, known as the Barnesville anticline. The Pittsburgh coal lies at an altitude of about 1,080 feet above sea level along its crest and dips southeastward to 920 feet on the south township line. The dip is locally arrested in terrace-like forms, such as are illustrated by the alternate spreading and close grouping of the contours on the structural map (Pl. XII, in pocket).

MINERAL RESOURCES.

The principal mineral products of Warren Township are coal, oil and gas. The oil and gas field lies on an anticline west of Barnesville and the product is derived from the Berea sand, which is about 1,600 feet below the Pittsburgh coal.

COAL.

The stratigraphic positions of the principal coal beds are shown in the geologic section on page 16.

PITTSBURGH COAL.

The Pittsburgh coal bed maintains a thickness of at least 4 feet through nearly all of Warren Township. The only exception known is a small area at Baileys Mills, where the coal is probably reduced in thickness by a sandstone "roll." Its character along the outcrop on Leatherwood Creek and branches is evident in dozens of openings, and there is no reason for believing that it is not equally good under cover farther east. At a few points along the foot of the hill southwest of Barnesville the coal is overlain by sandstone, which forms an uneven contact with the coal. Records of core drilling beyond the south-

eastern limits of Warren Township, in Wayne and Goshen townships, also show that at two places the value of the coal is somewhat impaired by an uneven contact of the overlying sandstone.

There are in the vicinity of Baileys Mills two coal mines whose output is shipped by railroad—the Cochran mine No. 2 of the Bixler Ohio Coal Co. and the mine of the Media Coal Co. In 1916 these were the only shipping mines operating in the Pittsburgh coal within the Summerfield and Woodsfield quadrangles. Samples were taken in the Cochran mine No. 2, and the results of the analyses are given on page 39. Sections of the bed are given on page 44. The average make-up of the coal bed is illustrated by the following measurement:

Section of Pittsburgh coal bed in G. Wellen mine, 1 mile west of Barnesville (locality 7).

	Ft.	in.
Coal	1	1
"Sulphur		½
Coal	1	9
"Sulphur"		½
Coal		11
Coal, bony		3
Clay.		
Thickness of bed	4	1

LOWER MEIGS CREEK COAL.

The Lower Meigs Creek coal bed is 2 feet thick in the greater part of Warren Township. It is seldom found free from "sulphur" and shale bands and has never been mined. It is of little importance, owing to the accessibility of the much more valuable Meigs Creek and Pittsburgh beds.

In the valley 1 mile northeast of Barnesville, where the Lower Meigs Creek coal has been exposed in the quarrying of the limestone that underlies it, a thickness of 2 feet 6 inches was measured. A shale band 4 inches thick is present 13 inches above the base. "Soot" streaks and "sulphur" impurities are also conspicuous. The Meigs Creek coal, lying 20 feet higher, has been mined here.

On both sides of Leatherwood Valley southwest of Barnesville the Lower Meigs Creek coal lies under sandstone and has been taken out for local use where exposed in hillside ravines. The following measurement was made below the railroad in the NE. ¼ sec. 20:

Section of Lower Meigs Creek coal on J. T. Forbes farm, sec. 20, Warren Township.

	Ft.	in.
Sandstone, coarse, massive	10	
Clay, bluish drab	1	2
Coal, bony	1	1
Coal, with thin streaks of bone and clay	1	11
Shale, dark blue	1	
Limestone	3	

A section similar to that just given was seen half a mile to the west, on the other side of Leatherwood Creek. The same coal is present in Cat Hollow, in sec. 19, where it is thicker than the Meigs Creek coal. It also appears as a blossom on the road 1 mile west of Barnesville but was not seen farther west, where the overlying sandstone becomes unusually prominent.

MEIGS CREEK COAL.

The Meigs Creek coal, which is second in value to the Pittsburgh, is present in workable thickness on the greater part of its outcrop in Warren Township. The principal exceptions are the south side of Cat Hollow and the extreme northwest corner of the township, where the value of the coal is doubtful. It occurs in workable thickness along Leatherwood Creek, northeast and north of Barnesville, and westward from Barnesville for about 2 miles. The coal is not so good as the Pittsburgh coal, and the bed is less accessible, especially in the ridges in the western half of the township; hence it has not been mined except in a small way, and few mines are now open. In the southeast corner of the township this coal is the only convenient source of fuel for the farmers and has been mined at numerous places along branches of Captina Creek. Its thickness is far from uniform and ranges from 2 to 4 feet.

The Meigs Creek coal has been mined for years in sec. 20 near the head of Leatherwood Creek to supply the Barnesville market. The minable portion of the bed as shown by the section (p. 46) is 3 feet 2 inches thick in the Thomas Davy mine (locality 63), on the west side of the valley. A sample was taken here for analysis, and the results appear on page 40.

In the Elmer Hoag mine, 1 mile northeast of Barnesville, in the valley west of Tacoma, the Meigs Creek coal consists of one bench 2 feet 8 inches thick, lacking persistent bands of "sulphur" or other impurities. A similar thickness is found in the hollow north of Barnesville. Near the head of Cat Hollow (locality 62), at the south side of the township, the coal is less than 2 feet thick.

OTHER COAL BEDS.

The Uniontown, Waynesburg, and Waynesburg "A" coal beds are all seen in roadside exposures in the eastern part of Warren Township but are everywhere too thin to be of present or prospective value. A few miles to the south, however, the Waynesburg coal attains a workable thickness, and to the east, in Goshen Township, both the Waynesburg and Uniontown coals are minable.

The Uniontown and Waynesburg coals are both exposed along the railroad within the limits of Barnesville. The Uniontown may be

seen in a cut a quarter of a mile southwest of the station, where it consists of 10 inches of bony coal overlain by carbonaceous shale and sandstone. The Waynesburg crops out at the east end of the tunnel near the station and consists of 13 inches of impure coal overlain by 8½ inches of bony coal.

LIMESTONE.

The principal limestone beds of this township are shown in the geologic section for Warren Township on page 90. The Lower Pittsburgh limestone is separated from the Pittsburgh coal by about 25 feet of sandy shale and clay with a thin limestone bed (Upper Pittsburgh limestone), at the top, close beneath the coal. A typical exposure of these beds may be seen in the railroad cut at the mine of the Media Coal Co., half a mile northeast of Baileys Mills, where the limestone consists of a single massive layer 4 feet thick, underlain by clay and nodular limestone.

The Lower Pittsburgh limestone is valuable chiefly for road metal and has been stripped for this purpose where accessible in the ravines. The bed is persistent, and a thickness such as that near Baileys Mills can be relied upon throughout the greater part of Belmont County.

The Fishpot limestone, below the Lower Meigs Creek coal is likewise of considerable value for road metal, although only a few feet thick. It has been extensively used on the roads near Barnesville. Where quarried at the Elmer Hoag coal mine, in the valley 1 mile northeast of Barnesville, it consists of several layers, the combined thickness of which is about 5 feet. The composition of the rock in this vicinity is shown by analyses on page 51. Similar exposures may be seen in the ravines on both sides of Leatherwood Creek. West of Barnesville, in secs. 27 and 33, the limestone has an ocherous yellow appearance and is too thin to be of value.

The Benwood limestone consists of numerous layers interbedded with clay and calcareous shale. The aggregate thickness of the beds is 60 to 70 feet. Some of the layers are sufficiently firm and durable to be used as road metal, but much of the limestone is argillaceous and on weathering decomposes to calcareous clay. Throughout the greater part of Warren Township the position of the Benwood limestone is occupied by sandy shale and locally by sandstone, especially in the western portion. Toward the east there is a gradual decrease in sandiness and the beds become more calcareous. The sandy shale and thin-bedded limestone commonly have ripple-marked surfaces and fossil sun cracks, indicating deposition in water of slight depth and temporary exposure to the air. The Benwood limestone is most prominent in the extreme southeast corner of the township, along North Fork of Captina Creek, where it is present in nearly typical form.

SANDSTONE.

The most conspicuous sandstone beds in Warren Township are the one below the Meigs Creek coal horizon and the one overlying the Waynesburg "A" coal. The positions of these beds are shown in the general section (fig. 2, p. 16).

Between the Meigs Creek and Lower Meigs Creek coals is locally a massive coarse-grained sandstone 25 to 40 feet thick. This is prominent on the south edge of the township and also in the hills 2 miles west of Barnesville. It has been used to a slight extent for bridge abutments and foundations and is well suited for such purposes. The sandstone overlying the Waynesburg "A" coal is conspicuous on all ridge roads leading south and east from Barnesville. It is loosely cemented and too friable to be well adapted for construction. It has been crushed and used for plastering sand and would probably be suited to use as a glass sand after washing.

GOSHEN TOWNSHIP.

SURFACE FEATURES.

The north boundary of the Woodsfield quadrangle is formed by the fortieth parallel of latitude, which extends through the north-central part of Goshen Township. The northern portion of the township, lying within the Flushing quadrangle, is crossed by the Baltimore & Ohio Railroad, on which are the villages of Bethesda and Belmont. The southern, more hilly portion has no villages but supports a fairly large rural population. In 1920 the township had 3,430 inhabitants.

The run-off of the portion within the Woodsfield quadrangle is carried by four principal streams—Long Run, Jakes Run, Bend Fork, and Joy Fork—all of which flow a little east of south and empty into Captina Creek. Their valleys, although only moderately deep and narrow, are followed by little-used wagon roads on which there are few houses, and the land is largely abandoned to brush and second-growth timber. Here and there are small clearings where tobacco is grown. On the ridges are numerous well-kept farms that form a marked contrast to those in the valleys. The least elevations on the floors of the valleys are about 960 to 1,000 feet above sea level. On the intervening ridges the elevation is generally 1,200 to 1,300 feet. Exceptionally high knobs are in secs. 14 and 9. The one in sec. 14 is marked "1364" at the triangulation station on the summit. The one in sec. 9, shown by the topographic map to be 1,380 feet above the sea, is occupied by a schoolhouse.

GEOLOGIC SECTION.

The direction of the drainage lines and their gradient in Goshen Township agree fairly closely with the direction and magnitude of dip of the rocks; hence the strata exposed along the valleys are much the same from localities near the sources of the streams southward across the township. In the valley of Long Run are exposed the lowest outcropping strata. The thickness of all the strata that crop out in the township is about 450 feet.

The beds at the surface in Goshen Township include the upper two-thirds of the Monongahela formation and about 250 feet of the overlying Washington. The stratigraphic sequence is illustrated by the following section, compiled from observations and measurements made at several places:

Geologic section in descending order of strata exposed in Goshen Township.

	Feet.
Washington formation:	
Shale or shaly sandstone, commonly reddish brown.	
Limestone, nodular, gray	3
Clay, shale, or sandy shale	57
Limestone, nodular or in continuous courses	2
Shale	39
Coal, Washington, in two layers with shale or clay between	2–3
Shale, sandy, grading into massive sansdtone in western part of township	55
Coal, Waynesburg "A," commonly consisting of two parts separated by 8 to 12 feet of shale; both beds thin.	
Clay shale, reddish brown, with nodular limestone or locally a thin bed of limestone	3
Shale, containing sandy layers and locally beds of massive sandstone; Waynesburg sandstone member	45
Monongahela formation:	
Coal, Waynesburg, present in minable thickness along outcrop in eastern part of township	1–4
Shale, sandy, or locally massive sandstone	50
Coal, Uniontown, mined on Jakes Run and Bend Fork	1–3
Clay shale with nodular limestone	6
Shale, sandy	27
Limestone, Benwood; many beds of limestone with interbedded clay and calcareous shale	68
Coal, Meigs Creek	2–4
Shale or shaly sandstone, unmeasured.	
Coal, Pittsburgh, not exposed in township; lies 100 feet below Meigs Creek coal.	

Many of the beds recorded in the above section change greatly in appearance from place to place. The coals are not persistent, sandstone occupies the place of limestone beds, and shale grades laterally into sandstone. In the western part of the township coarse sandstone overlies the Waynesburg "A" coal; farther east this sand-

stone gives place to red shale, clay, and limestone beds such as are typically exposed at the village of Hunter. Along Bend Fork the sandstones over the Waynesburg and Uniontown coals appear and disappear in a confusing manner.

STRUCTURE.

The dip of the strata, as shown by the contour map of the Pittsburgh coal (Pl. XII, in pocket), is a little south of east at a rate ranging from 15 to 60 feet to the mile. The amount of dip across Goshen Township is about 220 feet, the Pittsburgh coal being 970 feet above sea level at the greatest elevation and 750 feet at the least. The terrace-like undulations of the coal are shown by the alternate close spacing and spreading of the contour lines on the map.

MINERAL RESOURCES.

The principal mineral product in Goshen Township is coal. There are also sandstones that may be considered as of prospective value. No oil or gas of consequence has been discovered, but the township has by no means been thoroughly tested, and there is a possibility that valuable pools may be found here.

COAL.

The outcropping coals recorded in the general section (p. 16) vary considerably in thickness from place to place, and the limits of minable areas can be determined only by careful prospecting. The Pittsburgh coal, which lies below the surface, is far more reliable, and there is good reason for believing that it holds a thickness of at least 4½ feet throughout nearly all the township.

PITTSBURGH COAL.

The Pittsburgh coal is about 60 feet below the surface on Long Run, in the southwest corner of the township, and 160 to 180 feet below in the valley of Bend Fork. It has been tested by core drilling at five points and is recorded in a number of wells drilled for oil The records, except that of well No. 14, drilled on Long Run in section 31, indicate that the coal is of uniform thickness, approximating 5 feet. Additional information from adjacent areas leads to the belief that the Pittsburgh coal is a valuable bed throughout Goshen Township with the possible exception of the southwest corner. Core-drill record No. 14 shows the coal to be only 3 feet 4 inches thick and overlain by sandstone. About 1½ miles to the southeast, in sec. 23, Wayne Township, the bed is even thinner, being only 2 feet 5½ inches thick and overlain by sandstone as recorded in test hole No. 16.

A record of diamond-drill hole No. 17, on the T. J. Hatcher farm, in the valley of Bend Fork, in the NW. ¼ sec. 1, is given below. The elevation of the surface is 990 feet, and the depth to the coal 188 feet. The record was obtained from Prof. F. A. Ray, of Columbus, Ohio.

Record of core-drill hole No. 17, on T. J. Hatcher farm, Goshen Township.

	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Surface	11		11	
Limestone	7		18	
Soapstone	2		20	
Limestone	2		22	
Soapstone	2		24	
Limestone	5		29	
Soapstone	1		30	
Limestone	3		33	
Soapstone	1	6	34	6
Limestone	7	6	42	
Soapstone		6	42	6
Limestone		6	43	
Soapstone	1		44	
Limestone	22		66	
Soapstone	1		67	
Limestone	0	6	67	6
Soapstone	1		68	6
Limestone	26	8	95	2
Shale, dark	1		96	
Soapstone	3	1	99	1
Slate		1	99	2
Coal [Meigs Creek]	2	6	101	8
Limestone	12	2	113	10
Shale, gray	5	6	119	4
Slate	1	6	120	10
Coal [Lower Meigs Creek]	1	8	122	6
Fireclay	1	4	123	10
Limestone	13	6	137	4
Soapstone	1		138	4
Limestone	4	6	142	10
Soapstone		6	143	4
Limestone	3	6	146	10
Shale, light	5		151	10
Limestone	4		155	10
Slate, dark	3		158	10
Limestone	1		159	10
Shale, light	1		160	10
Limestone	7	6	168	4
Soapstone	1		169	4
Limestone	7		176	4
Soapstone	2		178	4
Limestone	1		179	4
Soapstone	4	3	183	7
Coal } [Pittsburgh coal]		9	184	4
Clay } [Pittsburgh coal]		10½	185	2½
Coal } [Pittsburgh coal]	5	4½	190	7
Limestone		3	190	10

The thickness of the Pittsburgh coal in the other coal test holes drilled in Goshen Township is as follows:

	Ft.	in.
Hole No. 18, SE. ¼, sec. 1	5	1
Hole No. 15, SE. ¼, sec. 16	6	1
NE. ¼, sec. 6	5	4½

MEIGS CREEK COAL.

The Meigs Creek coal, lying about 100 feet above the Pittsburgh, appears in outcrop in the valley of Long Run in secs. 25, 31, and 32. It has been mined temporarily at several places for country use, and

there are now two small mines in operation (Pl. III, *A*). The following section was measured in an opening on the A. H. Peddicord farm (locality 67), in the SW. ¼ sec. 25:

Section of Meigs Creek coal bed in Peddicord Mine, Goshen Township (locality 67).

	Ft.	in.
Clay, unmeasured.		
Coal	2	10
Clay		½
Coal	1	3
Clay shale.		
Thickness of bed	4	1½

A section similar to the above is reported a short distance north on Long Run. About 1½ miles downstream the thickness is somewhat less. The thickness of the Meigs Creek coal under cover on Bend Fork, as shown by several diamond-drill test holes, is represented in the following tabulation:

	Ft.	in.
Hole No. 18, SE. ¼, sec. 1	3	2
Hole No. 17, NW. ¼, sec. 1	2	6
Hole No. 15, SE. ¼, sec. 16	3	10

UNIONTOWN COAL.

The Uniontown coal bed crops out low in the valley of Bend Fork and Jakes Run and lies 100 to 130 feet above the valley floor of Long Run. It has been mined at numerous places on the first two streams, but is not believed to be present in minable thickness at any point along Long Run or its tributaries, and at several places where observed it consists largely of carbonaceous shale. The most promising exposure is at locality 100, in sec. 31 (see measurement, p. 101), where the coal is about 3 feet thick and contains three layers of shale each several inches thick.

The Uniontown coal is called the "Three-Foot soft coal" by the miners, in order to distinguish it from the Waynesburg, which is known as the "Four-Foot hard coal." It is as a rule high in ash and contains one or more shale partings 1 to 3 inches in thickness, which may be so intimately intercalated with the coal that their exclusion in mining is difficult. This feature is illustrated in the following section measured in the C. J. Van Fossen mine in the NE. ¼ sec. 20, a view of which is given in Plate IV, *A*:

Section of Uniontown coal bed in C. J. Van Fossen mine, Goshen Township (locality 101).

	Ft.	in.
Shale.		
Coal	1	1
Shale		1–4
Coal		11
Clay shale		3½
Coal		9
Shale.		
Thickness of bed	3	4½

In a drift recently opened on the Ewars farm, in sec. 13 (locality 10(nearly 1 mile downstream from the Van Fossen farm, the coal diffe from its usual appearance in that it is a bed 3 feet 11½ inches thic free from shale bands. No such favorable showing was seen els where.

The Uniontown coal has been mined in a small way at numero places on Bend Fork, and its character is illustrated by the secti given below.

Section of Uniontown coal bed on John Wharton farm, in sec. 15, Goshen Towns (locality 102).

	Ft.	in.
Sandstone, coarse, irregular bedded.		
Shale	4	
Coal, with shale streaks	1	10
Clay shale		4
Coal	1	1
Shale.		
Thickness of bed	3	3

In the Peter G. Kemp property, in sec. 1 (locality 103), the make- of the bed is similar to that shown above, but the thickness is onl feet 10½ inches. The measurements and results of analysis of a sam are given on pages 47 and 40, respectively.

On Bend Fork, especially in the southeast corner of Goshen To ship, cross-bedded sandstone lies close above the Uniontown coal a has locally affected the thickness and quality of the coal bed, wh is far from uniform. A measurement in the Gatten mine (local 104), near the south township line, gives a section similar to that the Kemp mine, but at several places less than 1 mile farther do stream the bed is too thin to be of value. It is likewise lacking wh the road crosses Packsaddle Run in sec. 15, where there is at its hori only a layer of dark clay overlain by cross-bedded sandstone.

WAYNESBURG COAL.

The area of minable coal in the Waynesburg bed in Goshen To ship is considerably less than that of the Uniontown, which lies feet lower. The Waynesburg, like the Uniontown, is invariably h in ash, an analysis showing 16 per cent; but it differs from the Un town coal in that shale bands are not common in the midst of coal bed. The Waynesburg coal is also hard and tough, and for reason is called the "Four-Foot hard coal" by the people who min The bed has a workable thickness along the greater part of Bend F in its course across Goshen Township and is also known to be of sl value near the head of Jakes Run and on Long Run and its bran in secs. 25 and 31. In the H. S. Phillips mine, at the center of sec (locality 123), the coal is 4 feet 1 inch thick and has no shale purities. The roof is massive sandstone about 12 feet thick.

other exposure of the Waynesburg coal was found in this vicinity. Where seen to the southwest, west, and north, at points about 1 mile distant, the coal is somewhat thinner. On the hill road leading west from the valley in sec. 31 the following section was measured:

Section of coal beds on road in sec. 31 (locality 100).

	Ft.	in.
Shale.		
Waynesburg coal:		
Coal, with earthy bands	2	3
Shale		1
Coal		2
Shale, sandy	40	
Uniontown coal:		
Coal, with earthy bands		6
Shale		4
Coal		2½
Shale		2
Coal		7½
Shale		3
Coal		10½
Clay.		

On the Mead farm, on a branch of Jakes Run in the SW. ¼ sec. 21 (locality 124), the Waynesburg coal has been stripped, and a thickness of 2 feet is reported. No workable thickness was discovered elsewhere on this stream except to the south, beyond the township line, where the bed has been mined near Hunter.

The Waynesburg coal is probably of minable thickness throughout its outcrop on Bend Fork, except in a portion of sec. 1 and in secs. 16 and 22, near the head of Packsaddle Run. On the roadside in the NW. ¼ sec. 15 (locality 126) a thickness of about 2 feet was observed. At the south edge of sec. 1, on the road leading west up the hill, the coal shows only a thin blossom. An unsuccessful search for the coal was made in the north-central part of the same section. Near the northwest corner there is an old opening (locality 129) in which the thickness is reported to be 3 feet. Westward in the hollow in sec. 7 (locality 128) a section measured in the J. D. Milhoan mine shows a thickness of 3 feet 2 inches. The analysis of a sample taken at the Milhoan mine is given on page 41 (No. 20174) and the detailed section on page 48. The heating value is similar to that of samples of Uniontown coal, being 11,610 British thermal units, but considerably less than that of the Pittsburgh coal, which averages about 12,800 British thermal units in this region.

Another measurement of the Waynesburg coal made in the Ross Gregg mine, in sec. 15 (locality 127), gives a thickness of 3 feet 6 inches of clear coal. No openings were found farther north on either branch of Bend Fork and information as to the thickness as represented on the map (Pl. VIII, p. 34) is based on roadside and ravine exposures, none of which permit accurate measurements of the bed.

On the east edge of the township, in the valley of Joy Fork, the coal has been mined both by stripping and by drifting, and the thickness is reported to be about 3 feet.

WASHINGTON COAL.

The Washington coal is far more persistent than either the Uniontown or the Waynesburg, being 1½ to 2½ feet thick throughout nearly all its outcrop in the township. It is of little value, however, on account of its high ash content and also because the bed is commonly divided into two benches by a layer of shale 6 to 18 inches thick. There are few places where the coal has been taken from underground workings, but it has been stripped where the cover is slight in dozens of ravines, and there is hardly a farm where it has not been prospected.

The principal evidence as to its thickness is obtained in roadside and ravine exposures. On the hillside at the south edge of sec. 13 (locality 77), east of Hunter, the coal is 2 feet 6 inches thick, and beneath it is 5 feet of clay shale, underlain in turn by 10 inches of coal. The Waynesburg "A" coal, exposed on the same road 50 feet lower, has a thickness of 1 foot 1 inch. Few opportunities were found elsewhere for measurement of the Washington coal, but it seems probable that the thickness of 2½ feet at Hunter is somewhat above the average and that the coal is 2 feet or slightly less in thickness in the northeastern part of the township. Its only use will be as a fuel for the farmers living on the ridges remote from other sources of supply.

Another coal 12 to 18 inches thick occurs 20 to 25 feet above the Washington coal in the northeastern part of Goshen Township. To the east, in Washington Township, this higher coal is in places more prominent than the Washington.

LIMESTONE AND SANDSTONE.

The principal limestone exposures in Goshen Township are in the valley of Long Run, where the Benwood limestone, overlying the Meigs Creek coal, crops out. Many of the beds are too argillaceous to be durable and hence are not well suited for use as road metal. There are, however, more resistant layers, especially near the top, which are excellent for this purpose. These uppermost beds form the valley floors of Jakes Run and Bend Fork, where they would furnish large quantities of easily obtainable material.

The strata above the Benwood limestone consist largely of sandstone, shale, and clay, with little limestone. Almost the only beds of limestone are above the Washington coal, one being 40 feet and another 100 feet higher. These limestones are conspicuously exposed in the vicinity of Hunter and in the ridges to the northeast. They consist of nodular limestone embedded in clay, or of one to three

continuous layers, each about 1 foot thick. These beds by their decomposition enrich the soil, but otherwise they are of little importance.

The most widespread sandstone members of this township overlie the Uniontown and Waynesburg coals. These are locally massive and favorable for quarrying and suited for use in bridge foundations and other structures. The less massive sandstone is so irregularly bedded that it does not favor easy quarrying. Small quantities of the rock are taken out from time to time for local use.

The sandstone overlying the Uniontown coal has its most prominent development along Bend Fork. It is as a rule cross-bedded and made up of lenticular layers which closely overlie the coal or are separated from it by a few feet of sandy shale. Few exposures show rock suitable for quarrying.

The Waynesburg sandstone in massive form is not present throughout large areas. At the Phillips coal mine, in sec. 25, it has a thickness of about 12 feet. A similar thickness was seen on Bend Fork and its branches in secs. 9 and 15.

SOMERSET TOWNSHIP.

SURFACE FEATURES.

Somerset Township is an area 6 miles square which in terms of the early land surveys is designated T. 7 N., R. 6 W. All the sections except those in the west and north rows have each an area of approximately 1 square mile. The principal villages are Temperanceville and Somerton, in the west and east central portions, respectively. The extreme northwest corner of the township is crossed by the Baltimore & Ohio Railroad, which follows the valley of Leatherwood Creek.

The time is not remote when one or more railroads will be built across the township for the exploitation of the Pittsburgh coal which underlies all but the extreme southwest corner. A favorable route would be from the west up Beaver Creek to Temperanceville, thence up the valley to the northeast, and through the divide into the Slope Creek valley by a short tunnel. The route down the Slope Creek valley past Somerton is direct and furnishes an excellent grade. From Somerton eastward in Wayne Township along South Fork of Captina Creek there would necessarily be numerous cuts, tunnels, and bridges, owing to the exceeding crookedness of the valley. North Fork of Captina Creek is less objectionable in this respect and could be reached by a route up Cat Hollow or Dog Hollow from Baileys Mills.

Somerset Township contains the dividing ridge which separates eastward-flowing tributaries of Captina Creek from westward-flowing

streams that empty into Wills Creek and eventually into Tuscarawas River. All the valleys west of this divide have a mature aspect that is lacking in those east of the divide. The valleys of the westward-flowing streams have been cut to a moderate gradient almost to their sources, and the streams flow in wide bottoms bordered by high ridges. These valleys at points 1 mile from their sources are uniformly about 1,000 feet above sea level, whereas across the divide to the east points on streams at similar distances from the sources are 100 to 150 feet higher. The 1,000-foot contour is not reached in branch valleys of Captina Creek within the township, being 5 to 6 miles from its headwaters.

All points on the principal divide are higher than 1,200 feet in elevation, and numerous summits extend above 1,300 feet. The ridge near the township line in sec. 30 is 1,360 feet above sea level, and several hills southeast of Boston reach about 1,350 feet.

The valley slopes have been terraced, as a result of the unequal hardness of the rocks, and this feature not only adds to the beauty of the hills, but aids in farming the land. Rain water in its downward percolation through sandy strata is interrupted by clay beds associated with coals, and the water is led to the surface along the terraces, forming springs that furnish a clue to the position of such beds. Certain sandstone members have locally attained great prominence, and several of these border the deep valleys in the western part of the township, producing shelving cliffs and massive blocks which contribute a picturesque beauty.

GEOLOGIC SECTION.

The deep valleys near the western edge of the township have been cut below the position of the Pittsburgh coal, which is mined in the vicinity of Temperanceville and in Dog Hollow. Its elevation at those places is a little more than 1,000 feet above sea level. The general southeastward dip carries the bed below 850 feet in elevation in the southeast corner of the township. In the valley at Somerton it is about 170 feet below the surface and the Meigs Creek and Lower Meigs Creek coals are also below the valley. The Waynesburg coal is mined in the neighboring hills, and the Washington, a still higher bed, crops out on the highest ridges. Its position is about 380 feet above the Pittsburgh bed. If the strata above the Washington coal and those outcroping below the Pittsburgh are included, the total thickness of rocks exposed in Somerset Township is about 530 feet.

An illustration of the nonpersistence of sandstone members is found in the beds lying between the Lower Meigs Creek and the Meigs Creek coals. In Dog Hollow, at Temperanceville, and farther south on the headwaters of Rock Creek massive, cliff-forming sandstone

occupies this horizon and extends above the position of the Meigs Creek coal, which is thin or lacking. Still farther south and west the sandstone gives place to shaly sandstone and shale and the Meigs Creek coal again appears in its normal position, 25 to 30 feet above the Lower Meigs Creek coal. The sandstone over the Uniontown coal shows a similar variation in character, being a prominent massive bed in the southwestern part of the township and thin-bedded to shaly in the vicinity of Somerton.

The thinning of the Pittsburgh coal from a bed 4 feet thick to a carbonaceous streak takes place abruptly, as is evident at Temperanceville. In several mines on the north and east sides of the village the coal maintains a uniform thickness of nearly 4 feet. To the southwest and west, however, at points less than half a mile distant, the coal is too thin to be of value, and in valleys to the south it is lacking. The usual limestone beds immediately beneath and about 20 feet lower are continuous and even more prominently developed where the coal is lacking than where it is of minable thickness.

STRUCTURE.

The direction and rate of dip of the Pittsburgh coal is represented on the structural contour map (Pl. XII, in pocket), which shows that there is considerable variation in Somerset Township. In the vicinity of Temperanceville and to the north the beds lie nearly flat, but a short distance to the east they dip nearly 90 feet in 1 mile toward a shallow depression southwest of Somerton. North of Somerton there is a flat promontory-like terrace bordered on the northwest by a synclinal embayment and depression. South of Somerton the rocks lie nearly flat for about 2 miles, beyond which there is another increase in rate of dip.

In mapping the geologic structure the elevations of certain key beds whose positions with reference to the Pittsburgh coal are known were determined. The principal key beds are the Waynesburg and Uniontown coals and the limestone beneath the Lower Meigs Creek coal. Elevations were obtained on these and other beds and also on oil-well drill holes at about 180 points in the township. The higher coals and other strata lie so nearly parallel to one another, and also to the Pittsburgh bed that a map showing the "lay" of any one of them indicates also that of the others.

MINERAL RESOURCES.

Coal, petroleum, and natural gas are the principal mineral products of Somerset Township and the only ones that have been exploited to any extent. The numerous sandstone beds afford convenient material for bridge foundations and are quarried in small quantities as

needed. Limestone is not present in large quantities, but the amoun in parts of the township is probably sufficient for putting most of th roads in good condition.

COAL.

The valuable coal beds of Somerset Township are in ascendin order the Pittsburgh, Lower Meigs Creek, Meigs Creek, and Waynes burg.

PITTSBURGH COAL.

The Pittsburgh coal bed crops out in Dog Hollow in the northwes corner of the township and also in valleys occupied by the branche of Beaver Creek at Temperanceville. It may also be seen along th two branches of Rock Creek in the southwest corner of the townshi where the coal is thin and of no value.

The bed has been mined at a number of places in Dog Hollow, bu all the openings have been abandoned and most of them have falle in. The following section measured at the south side of sec. 30 nea the schoolhouse is believed to be representative of the neighborhoo

Section of Pittsburgh coal bed on the Judkins farm, in sec. 30, Somerset Townsh (locality 10).

	Ft.	in.
Sandstone, unmeasured.		
Clay shale	3	
Coal, no persistent partings seen	3	11
Clay and limestone	2	

The quality of the Pittsburgh coal is shown by analyses of sampl taken in the Cochran No. 2 mine at Baileys Mills (Nos. 2018 20188, p. 39).

The Pittsburgh coal was measured and sampled in the Jefferi mine, a quarter of a mile southeast of the crossroads at Temperanc ville. The analysis (No. 20230) is given on page 39. The coal com pares favorably with that at Baileys Mills, being only slightly low in calorific value and a little higher in ash. A detailed section of t bed, about 3 feet 8½ inches thick, is given on page 45.

On the outcrop map (Pl. V, p. 28) is shown the approximate li dividing the valuable Pittsburgh coal to the north from the barr portion to the south. This line can readily be traced by numero old openings where the coal is good and unsuccessful prospects whe it fails. The coal is of doubtful value on the south side of the vall west of Temperanceville and is also lacking in the hills bordering t valley of Beaver Creek on the north, except in the immediate vicini of Temperanceville. From Temperanceville the line of divisi bears northwestward to the vicinity of Quaker City.

South of Temperanceville on the two branches of Rock Creek t position of the Pittsburgh coal is marked by a little carbonaceo shale or a thin coal streak overlying several beds of bluish limeston

The Lower Pittsburgh limestone is a prominent bed and can be traced continuously westward along the valley to its junction with Beaver Creek, thence eastward to the point where the Pittsburgh coal again appears as a valuable bed.

The bed at the Pittsburgh horizon is exposed in the valleys of Seneca Fork and Paynes Fork, the latter of which is 4 miles due south of Temperanceville, and is of no value in these valleys. To the east and south the bed is everywhere below the surface for many miles. Under cover it thickens to a valuable bed extending under Belmont County and the greater part of Monroe County to Ohio River and into West Virginia. The line of division between the thin and thick coal can be determined only by test drilling. The evidence at hand does not permit sharp definition of the limit, but it may be represented by a line drawn southeastward from Temperanceville to Boston, thence a little east of midway through sec. 19 to the county line. This approximate boundary is shown on the map by a broken line. It is drawn from evidence furnished by diamond-drill and oil-well (churn-drill) records. The latter are, for well-known reasons, far from reliable in proving the thickness of coal beds, but the combined data furnished by them are of considerable value. The Pittsburgh coal is reported in oil wells on the ridge 1 mile east of Temperanceville and also in wells drilled near the county line in sec. 13, 1½ miles southeast of Boston. The coal is reported in all the available records of wells east of this line. In core-drill hole No. 21, south of Boston, in sec. 19, the coal is 1 foot 9 inches thick, and in No. 22, half a mile down the valley to the southwest, there is no Pittsburgh coal. At that point the bed, if present, would lie about 180 feet below the surface. A partial record of drill hole No. 21 follows:

Partial record of core-drill hole No. 21 on Higginbotham farm in sec. 19, Somerset Township.

		Thickness.		Depth.	
		Ft.	in.	Ft.	in.
Sandrock		11	8	180	9
Shale, gray		2	7	183	4
Pittsburgh coal	Slate, coal, and limestone	1	9	185	1
	Coal	1	10	186	11
Limestone.					

The record of a diamond-drill test hole, No. 20, drilled at Somerton, in sec. 2, is given below.

Record of core-drill hole near Somerton.

[Surface 1,011 feet above sea level.]

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Surface	11		11	
Shale, soft yellow	1	6	12	6
Sandstone, gray	61	2	73	8
Clay, limy		4	74	
Slate and coal, Meigs Creek	1	9	75	9
Shale, limy, dark		5	76	2
Limestone	2	10	79	
Shale, hard dark		3	79	3
Limestone		6	79	9
Rock, cement	1	6	81	3
Limestone		7	81	10
Limestone with fossils		6	82	4
Shale, dark, hard		2	82	6
Limestone	3		85	6
Shale, black, hard		3	85	9
Limestone	1	3	87	
Rock, cement	3	6	90	6
Shale, greenish, sandy, with lime nodules	1	6	92	
Shale, clay	14		106	
Shale, greenish, sandy, with little lime	4		110	
Lime or iron nodules		3	110	3
Shale, gray, sandy	5		115	3
Sandstone, gray, place of Redstone coal	30		145	3
Shale, dark gray, with thin sandstone bands	2	9	148	
Sandstone, gray	1	3	149	3
Shale, dark gray		3	149	6
Sandstone, gray	2	3	151	9
Slate, dark, with fossils	3	4	155	1
Coal, slaty		3	155	4
Slate dark	2	11	158	3
Coal, Pittsburgh or No. 8	4	7	162	10
Slate, dark		2	163	
Shale, hard dark limy, fire clay	3	3	166	3
Shale with limestone nodules		9	167	
Limestone	1		168	

LOWER MEIGS CREEK AND MEIGS CREEK COAL.

The Lower Meigs Creek coal ranges from 1 foot to nearly 3 feet in thickness on its outcrop in the western part of Somerset Township. The Meigs Creek bed, which normally lies 20 to 30 feet higher, is of little or no value. Near the forks of Rock Creek in secs. 25 and 31 it is shaly and less than 18 inches thick, and also in the vicintity of Temperanceville it is no thicker. There is commonly a thick sandstone bed between the two coals, and where this sandstone is most prominent the upper coal is missing.

The Lower Meigs Creek coal has been mined to a slight extent at several places. In an old opening in sec. 25 the bed is about 30 inches thick and has seven to ten "sooty" bands. In spite of its unfavorable appearance, the coal is praised by the farmers who have used it. Close beneath the coal is invariably a bed of gray limestone.

Years ago the citizens of Somerton attempted to sink a shaft to the Lower Meigs Creek coal, which lies at a depth of about 75 feet in the valley. Funds were exhausted before the work was completed, and

the project was abandoned. The bed would have proved disappointing both in thickness and in quality, as indicated above in the record of coal test No. 20, drilled in the same vicinity.

The Meigs Creek coal lies low in the valley of Captina Creek in the extreme northeast corner of the township, where it is present in valuable thickness but varies greatly from place to place. The coal was formerly mined on the McVey farm, near the north township line, where, as reported, it is about 3 feet thick. Half a mile to the south, at the creek forks east of the township line, the bed is much thinner, but it thickens to 4 feet a short distance farther east, near the bend of the creek.

UNIONTOWN COAL.

The Uniontown coal bed is of no value in Somerset Township. Its position is marked by a few inches of carbonaceous shale and little or no coal.

WAYNESBURG COAL.

The Waynesburg coal bed crops out along valleys in all parts of the township and has been prospected at dozens of places. It is generally not more than 3 feet thick and is of poor quality, but at a number of places it is mined each winter to supply the local needs. The outcrop of the bed where it is believed to be of minable thickness is indicated on the maps (Pls. VIII and XII). The coal is probably of more or less value throughout the township except at the north and northwest borders.

Where mined on the N. Carter farm, in sec. 18 (locality 119), the coal is 2 feet 6 inches thick and has a roof of sandstone. At the center of sec. 24 (locality 116), on the roadside, it is a little less than 1½ feet thick. Toward the south it increases slightly in thickness, and at the head of Dog Hollow, in sec. 23, it measures about 20 inches, including several clay streaks. A measurement half a mile farther south on the road (locality 118) gives 2 feet, and a mile farther south, in the SW. ¼ sec. 22 (locality 120), the bed is 2 feet 2 inches thick.

The coal has been mined at a number of places near Boston and to the east. A section measured in the George Thomas mine, in sec. 14 (locality 145), shows the coal to be 3 feet thick, a little thicker than the average. The bed was sampled for analysis at this place (analysis 20241, p. 41), and a detailed section is given on page 48.

In the vicinity of Somerton and farther south the Waynesburg coal is thinner than in the Thomas mine. Numerous openings have been made, but few of them are now accessible for measurement. In an old opening in the NW. ¼ sec. 2 (locality 144), the thickness is a little less than 2 feet. North of Somerton, in an opening in the SE. ¼ sec. 4 (locality 121) the bed measures about 3 feet.

WASHINGTON COAL.

The Washington coal lies near the hilltops in the southern part of the township. It appears in numerous roadside exposures, most of which show the bed in two benches, with a layer of clay between. The following measurement is representative:

Section of Washington coal bed in the SW. ¼ sec. 13, Somerset Township (locality 87).

	Ft.	in.
Clay.		
Coal		5¼
Clay		4
Coal	1	5
Clay.		
Thickness of bed	2	2¼

SANDSTONE AND LIMESTONE.

The local demand for sandstone is slight, for its only use is for bridge and building foundations. There are in nearly all parts of the township materials suited for this purpose, and in small areas some of the beds could be quarried on an extensive scale for building stone.

The most valuable sandstone is found above the Uniontown coal in the southwestern part of the township, where it occurs in a thick massive ledge lacking the irregular bedding lines so prevalent at other places. This rock was quarried to the south, in Malaga Township, and used in the construction of the stone church near Miltonsburg.

Two other sandstone beds deserve mention. One lies above the Meigs Creek coal and is conspicuous in the hills at Temperanceville and to the south along the branches of Rock Creek. The other is the sandstone lying under the Washington coal and about 60 feet above the Waynesburg coal. This sandstone, which is correlated with the Mannington sandstone of West Virginia reports, appears in massive form in the ridges in the northern part of the township. It is less durable than the Uniontown sandstone, and its friable beds readily crumble into sand.

Somerset Township, like most other parts of Belmont County, contains limestone in numerous thin layers between sandstone, clay, coal, and other beds. The greatest quantity occurs in the deep hollows of Rock Creek west of Boston. The thickest beds lie near the horizon of the Pittsburgh coal; a thinner layer occurs beneath the Lower Meigs Creek coal. The same beds are prominent on Beaver Creek near Temperanceville.

The Benwood limestone, which is so prominent along Captina Creek in Wayne Township, is of less value at Temperanceville and other places in the western part of Somerset Township. Its uppermost layers crop out in the valley slopes near Somerton and have been used in surfacing the road. The same limestone occurs in consider-

able quantity in the northeast corner of the township. Many of the beds are clayey and lack durability.

WAYNE TOWNSHIP.

SURFACE FEATURES.

Captina Creek and its branches have carved deep valleys in the plateau of Wayne Township, making its surface one of the most hilly in eastern Ohio. North and South forks unite in the east-central portion, forming the main creek, which flows eastward to Ohio River. Captina Creek and its branches follow meandering courses in narrow flood plains bordered by steep hills that rise 300 feet or so above the valley floors. The slopes of the hills are largely controlled by thick sandstone beds that appear as sheer walls along the rims of the valleys, forming numerous picturesque shelving caverns and "rock houses." The course of South Fork is extremely meandering. Terraces border the valley at elevations of 920 to 950 feet, or about 70 feet above the present flood plain, and some of them are covered with gravel. The terraces suggest that the course of the ancient higher valley was considerably less tortuous than that of the modern valley.

The hills away from the valley rise to a general elevation of a little more than 1,200 feet, and a few isolated summits are above 1,300 feet. The summit occupied by the triangulation station near Newcastle is 1,367 feet above sea level.

GEOLOGIC SECTION.

The Meigs Creek coal crops out along North and South forks of Captina Creek. Its northwestward rise is about the same as that of the valley, and in no place is it more than 40 feet above drainage level. Near the junction of the two forks the coal dips below the bed of the creek, and thence eastward to the township line it is 10 to 15 feet below drainage level. About 100 feet lower is the Pittsburgh coal, which will at some future date support a great mining industry. The beds above the Meigs Creek coal to the tops of the highest hills comprise a thickness of about 400 feet, and their sequence is illustrated in the following section, compiled from measurements made in various places in the township.

Generalized section, in descending order, of strata exposed in Wayne Township.

	Feet.
Washington formation:	
Limestone, dark gray, nodular or in layers	2
Shale, sandy, or reddish-brown clay	55
Limestone, nodular or in layers	1½
Shale, carbonaceous, with clay and nodular limestone below	9

	Feet.
Washington formation—Continued.	
Shale, sandy, with one or more limestone layers and locally red clay	70
Clay shale, reddish brown	10
Limestone in two or more layers	2–4
Shale, sandy	26
Shale, carbonaceous, thin.	
Limestone, dark, shaly, with fragments of minute fossils	1
Shale	15
Coal, Washington, commonly in two benches separated by a layer of clay	2±
Clay and shale	15
Sandstone from thin bedded and irregular to coarse and massive, locally missing and sandy shale instead	45–50
Coal, Waynesburg A	1±
Limestone, yellowish, nodular in clay	2
Shale, sandy or clay shale with one or more layers of nodular limestone	45
Monongahela formation:	
Coal, Waynesburg	3±
Shale, sandy	16
Coal thin.	
Limestone, yellowish, in numerous layers	5
Shale or shaly sandstone	30
Coal, Uniontown, locally absent	3±
Clay shale	9
Sandstone, shaly	18
Shale, greenish gray and dark red	9
Limestone and calcareous clay, lower portion locally replaced by sandstone	67
Coal, Meigs Creek	3±
Sandstone or sandy shale	23
Coal thin.	
Limestone, well suited for use as road metal	5
Interval rocks not exposed to Pittsburgh coal	75

For purposes of geologic study a rugged topography such as found in Wayne Township usually offers advantageous conditior The narrow canyonlike valleys of Captina Creek and its branch present numerous excellent rock exposures, which permit detail study of all the 400 feet of strata exposed in the township. In t upper portion of the section is the great sandstone that borders t scenic valleys of Long Run and Piney Creek east of Newcast forming sheer walls 40 to 50 feet high and numerous overhangi ledges along the smaller ravines. Access to such valleys is not ea from the hills, and the narrow bottoms are followed by trails u worthy of the name roads, which lead to the few cabins that ha been built on them. The sandstone in massive form is promine only in the southeast quarter of the township and grades into fin bedded, sandy layers toward the west and north, there being san shale of reddish-brown color at this horizon in parts of the townshi

The Waynesburg coal, about 50 feet below the sandstone just described, and the Uniontown coal, 50 feet still lower, are the principal beds that have been mined in Wayne Township. As these are the most important coal beds in the hills, any prospect or mine is almost certain to be in one of the two. The Meigs Creek coal, 100 feet below the Uniontown, is also valuable, but the bed lies low in the valley of Captina Creek and is beneath the creek in part of the township.

Above the Meigs Creek coal is the Benwood limestone, consisting of calcareous clay interbedded with argillaceous limestone in numerous layers 1 to 2 feet thick and varying considerably in appearance and durability. The Benwood is about 65 feet thick, being the thickest limestone member in the entire "Coal Measures" of eastern Ohio. The limestone is lacking in fossils of marine types, such as crinoids and brachiopods, but contains fish bones, small gastropods, and other minute fossil shells called *Spirorbis*, all representing forms believed to have lived in fresh or slightly brackish water. A thin-bedded shaly gray limestone about 25 feet above the Meigs Creek coal is especially prolific in these remains. The Benwood limestone in typical development may be seen at many places on South Fork of Captina Creek east of Somerton, in secs. 27 and 33, and thence eastward to the township line. One of the most peculiar appearing and characteristic beds is found about 15 feet above the base. It has an angular, checkered surface made up of cubes that have curved surfaces and sharp edges. In fact, the beds resemble flint clay in appearance but are shown by the acid test to contain considerable lime. These beds, which are 2 to 4 feet thick where they crop out along Captina Creek, give certain evidence as to the depth of the Meigs Creek coal where it lies below the stream bed. Over this blocky limestone are green clay and thin-bedded limestone grading up into the platy fossil-bearing limestone beds described above.

Shale associated with coal beds commonly contain beautifully preserved impressions of ferns and other plants that were buried in the coal swamp in Carboniferous time. A collecting place was found near the north edge of sec. 9, about 200 feet below the ridge road, in shale that underlies the Uniontown coal, which is mined for home use on the George Garrett farm.

STRUCTURE.

The geologic structure or "lay" of the rocks in this township is expressed on the map by means of structural contours that show the attitude or dip of the Pittsburgh coal throughout the township. As all strata near the surface are nearly parallel the map is almost

equally useful in showing the attitude of all the coal beds. The dip is southeastward at a rate ranging from 15 to 70 feet to the mile, with local variations in direction and degree of dip that produce terraces, "noses," and "embayments" such as those in the southwest corner of the township. The utility of the structural map in determining the depth and direction of dip of the Pittsburgh coal at any point is evident, as the contours are drawn on that bed.

MINERAL RESOURCES.

Coal is the principal mineral resource of Wayne Township, the entire township being underlain by beds that will be mined in a commercial way in the not distant future, when transportation facilities are provided by the building of a railroad along Captina Creek. Sandstone formations deep below the surface have been proved of considerable value as sources of oil and gas, and there is a possibility of extension of the productive pool. There are four principal pools in which oil and gas are produced—the Brushy Creek, Newcastle, Stumptown, and Cow Run pools. The most productive sand is the Big lime. Limestone in quantity sufficient for the construction of good roads is fairly well distributed throughout the township, and sandstone suitable for rough construction work is abundant.

COAL.

The stratigraphic positions of the principal coal beds that crop out and lie below the surface are shown in the general section for Wayne Township (pp. 111–112). These beds are, in ascending order, the Pittsburgh, Meigs Creek, Uniontown, Waynesburg, and Washington coals.

PITTSBURGH COAL.

The Pittsburgh coal lies 80 feet or more below the surface in Wayne Township. It is recorded in all oil wells whose records have been obtained, and its thickness is known from test holes drilled in secs. 10 and 23. A record of test hole No. 19, in sec. 10, is given below through the courtesy of Prof. F. A. Ray.

Condensed record of core-drill hole No. 19, sec. 10, Wayne Township.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Surface, place of Meigs Creek coal	8		8	
Interval, mostly sandy shale	26	6	34	6
Coal, Lower Meigs Creek		3	34	9
Interval, limestone, shale, clay, and sandy beds	33	2	67	11
Coal and black slate, Pomeroy	1	3	69	2
Interval, mostly shale and limestone	25	4	94	6
Pittsburgh coal: Coal		10	95	4
Pittsburgh coal: Clay	1		96	4
Pittsburgh coal: Coal	5	7	101	11
Clay	4	1	106	

The well test in sec. 23 (No. 16) was not so favorable, showing only 2 feet 5½ inches of coal, divided into two parts by a thin layer of shale. Above the coal is sandstone, as was found 1½ miles to the northwest, in Goshen Township, where the coal bed is likewise below the normal thickness. These two measurements constitute the only available evidence of an unfavorable nature concerning the Pittsburgh coal in Wayne Township. All the oil-well records serve to support the belief that practically the whole township is underlain by the coal in valuable thickness. There are, it is true, areas of 1 square mile or more where no drilling has been done, but from the generally reliable character of this great coal bed it seems safe to assume its persistence.

MEIGS CREEK COAL.

The outcrop of the Meigs Creek coal, as shown on Plate VI (p. 32) follows the valleys of Captina Creek and its branches, but the coal passes below the creek bed in sec. 10. On South Fork the coal is exposed for a distance of slightly more than 1 mile. At the east side of sec. 33 the coal if present lies about 10 feet below the creek bed, as is indicated by the positions of certain limestone key strata seen there.

The lower part of the Benwood limestone, which rests upon the Meigs Creek coal, has been replaced by a coarse sandstone lens in parts of sec. 21 and at other places in the township. It has been observed that where this sandstone assumes prominence the Meigs Creek coal is commonly thin. Below the Meigs Creek coal is sandy shale which likewise gives place to massive sandstone that locally extends above the position of the coal and unites with the sandy beds above. It is certain that the Meigs Creek coal is thin or lacking in places, especially in the south half of Wayne Township. Its usual position is 90 to 100 feet above the Pittsburgh coal. Well records in the oil field at Newcastle show coal about 70 feet above the Pittsburgh, which is designated the "Mapletown," and that bed is doubtless the Lower Meigs Creek, and the Meigs Creek coal is lacking. Well records in the Brushy Creek pool and neighboring territory likewise indicate that the Meigs Creek coal is generally thin and that the Lower Meigs Creek coal is the one commonly recorded.

The thickness of the Meigs Creek coal on its outcrop is illustrated by several sections and accompanying notes. In the SW. ¼ sec. 36, along North Fork of Captina Creek, the coal varies considerably in thickness and at one point is lacking. Downstream, in the north central portion of sec. 35 in an opening on the King farm (locality 70), a thickness of 4 feet 1½ inches of clear coal was measured. The coal lies between two thick sandstone beds, which are separated from it by a few feet of shale.

The variable character of the beds overlying the coal is apparent from the following sections measured on the road leading up the hill

half a mile east of the King mine (locality 71), where the coarse sand-stone has disappeared and greenish shale and limestone of the Ben-wood member are found.

Section of beds overlying Meigs Creek coal in sec. 29, Wayne Township.

	Ft.	in.
Clay and shaly limestone.		
Limestone, creamy yellow, argillaceous	5	
Chert, dark colored		2
Limestone, shaly and chalky	2	
Shale, calcareous, greenish	17	
Coal, Meigs Creek, thickness not evident.		

At the junction of Long Run with North Fork of Captina Cree (locality 72) a thickness of slightly more than 2 feet was notice A mile up Long Run, in a coal mine on the Turner farm (locality 68 the coal is 3 feet 3 inches thick, but about a quarter of a mile farth upstream, near the forks of the road, where several prospect pi have been dug, a thickness of 16 inches was observed. Near th crossroads in sec. 17 the coal is less than 2 feet thick.

Exposures of the Meigs Creek coal in the vicinity of the junctio of the two forks of Captina Creek are not good, because the coal li at or near water level. From portions of the bed seen in the cree at several points it seems probable that the thickness is 2 to 3 fee

UNIONTOWN COAL.

On the map (Pl. XII, in pocket) the outcrop of the Uniontown co is represented where it is believed to be of workable thickness. Tl extent of the bed is further illustrated by the index map (Pl. VI p. 32). The area where the coal can be considered as of value occ pies the northeast quarter of the township. Elsewhere the coal commonly so intimately intercalated with shale that it is worthle and in other places the bed consists of bony shale. The bed at be can not be compared with the Meigs Creek or Pittsburgh, because is invariably high in ash and contains one or more layers of shale.

The thickness and character of the coal in the valley of Long Ru in the northwest corner of the township, is represented by the f lowing section, measured a short distance north of the township lir

Section of Uniontown coal on road in sec. 31, Goshen Township (locality 100).

	Ft.	in.
Coal and thin shale films		6
Shale		4
Coal		2½
Shale		2
Coal		7½
Shale		3
Coal		10½
Shale.		
Thickness of bed	2	11½

South and west of Long Run, in the valley of North Fork of Captina Creek, the Uniontown coal was nowhere observed in workable thickness, and toward the south the carbonaceous material marking its horizon becomes very thin. There is little or no Uniontown coal on South Fork and its tributaries, the coal bed mined in that drainage basin being the Waynesburg, which lies about 50 feet above the Uniontown. In the valley of Piney Creek, in the southeast corner of the township, there is only a thin layer of carbonaceous shale to mark the place of the Uniontown coal.

The only place on the south side of Captina Creek valley where the coal was found exposed in a prospect is on the George Garrett farm, near the north edge of sec. 9 (locality 109), where the coal bed has a thickness of 3 feet 3 inches and is overlain by 6 inches of carbonaceous shale.

About 2 miles northwest of the Garrett prospect a roadside exposure in the SW. ¼ sec. 17 (locality 108) shows a thickness of about 2 feet. North of this place the bed thickens and for a distance of several miles along Jakes Run its value has been proved by a number of openings. In an old prospect at the extreme southeast margin of sec. 24 (locality 107) the thickness is about 3 feet. Half a mile northwest of Hunter, at locality 106, a thickness of 3 feet 11 inches was measured in an opening recently made. No shale impurities were found in the coal.

East of Jakes Run, on Mikes Run, Berry Run, and other tributaries of Captina Creek, the thickness of the coal is known only from ravine and roadside exposures. It is believed to be somewhat less than that at Hunter but probably as much as 2 feet.

A measurement made in the D. H. Hatcher mine, Bend Fork in sec. 6, in the extreme northeast corner of the township (locality 105), gives the following result:

Section of coal bed in D. H. Hatcher mine, sec. 6, Wayne Township.

	Ft.	In.
Shale grading up into flaggy limestone.		
Coal	1	11
Bone		1
Coal		4
Shale		2
Coal		6
Shale.		
Thickness of bed	3	

A similar thickness was measured in another opening on the west side of the valley a few hundred feet north of the township line (locality 104). Downstream near the east township line the coal thins and is of doubtful value for a distance of about half a mile.

WAYNESBURG COAL.

Probably three-fourths of Wayne Township is underlain by the Waynesburg coal in thicknesses of 2 to 3 feet. The principal areas where it is known to be of little value are in the northeast and northwest corners, in secs. 5, 6, 12, 24, 29, 30, and 36.

The many openings made on Piney Creek and its tributary Long Run give an average thickness of about 2 feet for the coal. About 17 feet lower is a thinner coal bed resting on yellowish-brown limestone in a number of layers. In the SE. ¼ sec. 9 (locality 140), the following section was measured:

Section of Waynesburg coal in sec. 9, Wayne Township.

	Ft.	in.
Coal, bony		7½
Coal	1	3
Clay		3
Coal		4½
Shale.		

Near the forks of the creek half a mile farther east, at locality 141, a thickness of 2 feet 9 inches was measured. The bed where mined south of Piney Creek is in places free from shale bands but contains bony layers.

About 1 mile west of the mines on Long Run and half a mile northeast of Newcastle, in a ravine near the crossroads (locality 139), the Waynesburg coal is 6 to 18 inches thick and has an undulating roof of sandstone.

In the southwest quarter of the township, west of Newcastle and on Brushy and Cranenest creeks, there are numerous places where the coal has been prospected and temporarily mined in a small way. The thickness is generally 2 to 3 feet, and only one place was observed where the bed is as thin as 1 foot—in a roadside exposure at the south side of sec. 20 (locality 142). A section of the bed believed to be representative of this coal in the southwest quarter of the township was measured in the Howard Brown mine in sec. 26 (locality 143), where a sample of the coal was taken for analysis (No. 20234, p. 41). A section of the bed 2 feet 6½ inches thick is given on page 48.

A slightly greater thickness probably as much as 3 feet, was found in an opening at the north side of sec. 27 (locality 138), and also at a place near the east edge of sec. 33.

No prospect pits in the Waynesburg coal were found in secs. 24, 29, 30, 35, and 36, and roadside exposures indicate that the bed is not present in minable thickness. Northward beyond the township line, however, there is an area of thicker coal. The bed also thickens toward the east. In an opening on the McEndree farm, in the NE. ¼, sec. 22 (locality 137), 3 feet of clear coal was measured. A mile north of this place, on the west side of Jakes Run, the coal is 2 feet 10 inches

thick, and at the east edge of sec. 16 (locality 136), a little more than 1 mile southeast of that locality, the thickness is about 3 feet.

Near the center of sec. 18, on the hill road southwest of Hunter, the coal has been mined, but no openings are accessible. A natural exposure in that vicinity (locality 130) showed a thickness of about 2 feet.

A coal, probably the Waynesburg, has been mined to a slight extent on Mikes Run on the Price farm, in sec. 12 (locality 132). The bed is in two parts separated by about 1½ feet of shale; the lower bench is about 2 feet thick, and the upper bench is thinner and shaly.

A measurement on the John White farm, in the north-central part of sec. 4 (locality 134), shows 2 feet 6 inches of hard, tough coal overlain by 4 inches of bony coal and underlain by sandy shale. Information obtained east of Wayne Township indicates that the bed is increasingly valuable in that direction.

In a prospect on the Wallace farm, north of Captina Creek, in sec. 10 (locality 135), the coal is in a single clear bed 3 feet 2 inches thick, with a grading up into sandstone.

Near the southwest edge of sec. 10 (locality 136) is another opening in which the coal closely resembles the bed as found at the Wallace prospect.

WASHINGTON COAL.

The Washington coal lies 105 to 120 feet above the Waynesburg coal and 365 to 385 feet above the Pittsburgh. It is probably present throughout Wayne Township in thicknesses ranging from 1 to 3 feet for the upper and thicker bench, there being commonly two benches separated by 6 inches to 5 feet of clay. The coal has been stripped at dozens of places for home use, but has rarely been extracted from underground workings. Although high in ash, an analysis showing 21 per cent, the coal compares favorably with the Waynesburg and Uniontown of this region, being only a little lower in heating value. Few exposures that permit accurate measurement are available, but there are many places on road sides and in ravines where approximate results can be obtained, some of which are given.

Section of Washington coal on road east of Hunter, Wayne Township (locality 77).

	Ft.	in.
Shale.		
Coal	2	6
Shale, carbonaceous	5	
Coal		10

Section of Washington coal on Davis farm on the west side of sec. 9, Wayne Township (locality 80).

	Ft.	in.
Clay shale, with carbonaceous streaks.		
Coal, with clay streaks	2	4
Clay		3
Coal, impure	1	4
Clay.		

On the E. Moore farm, near the center of sec. 2, the coal is 2 feet 4 inches thick. On the T. C. Perkins farm, in sec. 6 (locality 78), the upper bench is about 2 feet 7 inches thick. In the northeast corner of sec. 17 (locality 79), on the Russell farm, the section in descending order is coal 2 feet 9 inches, clay shale 5 feet, coal 2 feet. On the ridge road at the southwest corner of sec. 27 (locality 86) the thickness is about 1 foot 3 inches. The bed is apparently at its best from Hunter and Newcastle eastward in the east half of the township and thinnest in the southwestern part.

LIMESTONE.

The principal limestone beds of Wayne Township are in the Benwood limestone member, overlying the Meigs Creek coal. The layers form "pavements" at many places on the valley floors of Captina Creek and its tributaries and are exposed in the steep valley sides, thus furnishing a large quantity of easily accessible road material for all parts of the township. Nevertheless not a mile of limestone pike has been built, and the roads are almost impassable except in the dry summer period. A slight attempt has been made at improving them, and the main traveled routes are graded into a rounded surface to prevent wash and facilitate drainage, but only the sandy ridge roads continue good after a few days of wet weather.

Probably the most durable and therefore the most valuable limestone beds of the Benwood member occur near the top, about 25 feet below the Uniontown coal. These beds include one layer that is especially persistent. It is about 2 feet thick, gray in color, smooth textured, and of laminated appearance on the weathered surface. The typical appearance of the lower beds of the Benwood limestone is illustrated by Plate X, *B* (p. 54). They consist of many layers interbedded with calcareous clay, some of which are sufficiently durable for road metal, whereas others are argillaceous and decompose readily on weathering.

In the southeastern part of the township, where the sandstone over the Uniontown coal is thin and less massive than in other localities, there is a limestone in the upper portion of the Uniontown-Waynesburg interval. This limestone is prominently exposed in the beds of Piney Creek and tributaries, where its brownish-yellow resistant layers form "cobble pavements." The stratigraphic position of this limestone is illustrated by a measurement made on the hill road at the east side of sec. 3 (locality 131).

Section of Waynesburg coal and associated strata in sec. 3, Wayne Township.

	Feet.
Shale, sandy.	
Coal, Waynesburg	2
Shale	16
Coal	½
Limestone, in brownish-yellow layers	10±

A. SANDSTONE OVERLYING MEIGS CREEK COAL AT MOUTH OF BRUSHY FORK OF CAPTINA CREEK.

B. QUARRY IN SANDSTONE NEAR WOODSFIELD.

Another valuable limestone occurs 40 feet above the Washington coal throughout the township. It is most prominent near the east border, where its thickness is 3 to 5 feet. The rock little weathered in ravine exposures is sufficiently durable to furnish excellent material for road metal. Along the south edge of the township this bed is thinner and occurs in nodules rather than layers. Still farther south the bed disappears entirely. The hills in the west half of the township contain several limestone beds 50 to 100 feet above the one just described. These, together with reddish clay beds, form the summits of ridges southeast of Hunter and east of Newcastle.

SANDSTONE.

Sandstone of various kinds is plentiful in Wayne Township. There are coarse beds 25 to 40 feet thick with no bedding planes, sandstone in irregular lenticular beds, and even-bedded flagstones that can be quarried in slabs.

Rock of the massive, coarse type is particularly abundant east of Newcastle, along Piney Creek and its branches. The geologic position of this sandstone is below the Washington coal and above the Waynesburg coal. The rock is not firmly cemented but is sufficiently resistant to crushing stresses to be useful for foundations. Sandstone of similar character but not so thick is found below and also above the Meigs Creek coal at a few localities on Captina Creek and its branches. The Meigs Creek coal at the mouth of Jakes Run, in sec. 17, is underlain by coarse sandstone more than 18 feet thick. Toward the north and west this bed loses its massive character and becomes flaggy. Sandstone replaces the lower portion of the Benwood limestone on Brushy Creek in secs. 21, 26, and 27. It is irregularly bedded and grades into shale along its outcrop. The appearance of this sandstone near the mouth of Brushy Creek is shown in Plate XI, *A*.

WASHINGTON AND SMITH TOWNSHIPS.

Washington and Smith townships adjoin Wayne and Goshen townships on the east, and a narrow strip along their west edges is included in the Woodsfield quadrangle. Excellent exposures of the rocks are found in the deep valleys of Captina Creek and its tributaries.

COAL.

The minable coal beds of this area include the Pittsburgh, Meigs Creek, Uniontown, Waynesburg, and Washington. These coals, with the exception of the Pittsburgh, which is 100 feet or more below the surface, are mined by the farmers at numerous places along their outcrops.

PITTSBURGH COAL.

The Pittsburgh coal has been tested by core drilling at a number of places in both townships. Records of tests obtained lead to the belief that the whole area is underlain by a bed of coal 5 feet or more thick.

MEIGS CREEK COAL.

The Meigs Creek coal lies about 100 feet above the Pittsburgh. At the west side of Washington Township it is about 15 feet below Captina Creek. About 3 miles farther east, beyond the limits of the area represented on the map, in the big bend of the creek 1 mile north of Alledonia, a station on the Ohio River & Western Railroad, the coal rises above drainage level and has been opened by Shipman Bros. The coal is also at the surface for a short distance along Bend Fork to the north.

Section of Meigs Creek coal bed in Shipman Bros.' mine, north of Alledonia.

	Ft.	in.
Roof, clay and limestone.		
Coal	2	1
Coal, bony cannel		2½
Coal		1½
Clay		½
Coal	1	6
Floor, clay shale.		
Thickness of bed	3	11½

A sample of the coal in Shipman Bros. mine was taken for analysis (No. 20237, p. 40).

The thickness of the Meigs Creek coal, in a diamond-drill hole at Alledonia, was found to be 2 feet 8 inches, and that of the Lower Meigs Creek coal, about 18 feet lower, 1 foot 9 inches.

UNIONTOWN COAL.

The Uniontown coal, lying about 100 feet above the Meigs Creek coal, is mined at many places on Joy Fork and Bend Fork, in the southwest corner of Smith Township and in Goshen Township, to the west. It is also mined in secs. 30 and 36 of Washington Township, but is of variable thickness and has an undulating sandstone roof. Farther south, in the western part of the same township, in the valley of Captina Creek and also to the south up Crabapple Creek, the coal is merely a faint blossom in most places, and the Waynesburg coal bed, 50 feet higher, is the principal source of fuel for the farmers. On the map (Pl. XII, in pocket) are represented the outcrops of all coal beds where known to be of minable thickness. This map should be studied by the reader who wishes information concerning specific localities.

In places on Bend Fork and its tributary Joy Fork both the Uniontown and Waynesburg coals are mined. The Uniontown is as a rule divided into two benches by a band of clay several inches thick; the Waynesburg is usually in one bench 3 to 4 feet thick. The typical structure of the Uniontown coal is illustrated by a measurement made in the extreme northeast corner of Wayne Township, on the east bank of Bend Fork (locality 105, Pl. VII, p. 32). Half a mile downstream from locality 105, across the line in Washington Township, the coal is too thin to be of value, but it thickens still farther downstream and is mined near the mouths of Joy Fork and Millers Run.

WAYNESBURG COAL.

The Waynesburg coal is most valuable in the western part of Washington Township south of Captina Creek, on Crabapple and Piney creeks. The bed is also of more or less value to the north in parts of Smith Township. It is mined at several places on Joy Fork, where that stream follows the township line, and is generally 2½ to 3½ feet thick.

A representative measurement of the coal bed where mined on Crabapple Creek was measured in the Stoffel mine, on the Nathan Davis farm, on the east side of the valley halfway between Crabapple and Alledonia stations, about half a mile east of the area represented on the map.

Section of Waynesburg coal bed in Stoffel mine, near Alledonia.

	Ft.	in.
Roof, shale.		
Coal, bony		4
Coal	2	5½
Floor, clay shale.		

The analysis of a sample of coal from the Stoffel mine is given on page 41 (No. 20236).

WASHINGTON COAL.

The Washington is the highest coal bed in the stratigraphic column of this area. It lies about 100 feet above the Waynesburg coal. The bed is of little value, partly because of its impurity and partly for the reason that there is generally a foot or so of clay shale near the middle, which is a hindrance in mining. In the same general region are the lower coal beds, which are thicker and more easily accessible, and therefore little attempt has been made to mine the Washington coal. The bed shows much greater uniformity throughout large areas than most other coals of this region. Its thickness is illustrated by a single section measured in an opening on the S. A. Moore farm, in sec. 33, Washington Township (locality 81).

Section of Washington coal on S. A. Moore farm, sec. 33, Washington Township.

	Ft.	in.
Roof, shale.		
Coal, bony		3
Coal, bony in lower part	2	1
Clay		8
Coal		11
Floor, shale.		
Thickness of bed	3	11

The analysis of a sample taken in the Moore mine is given on page 41 (No. 20238). The ash content is 21.0 per cent, more than twice that of an average sample of Pittsburgh coal.

MONROE COUNTY.

SENECA TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Seneca Township includes a part of the original square township designated by the early land survey T. 7 N., R. 7 W. The two west columns of sections have been added to Marion Township, Noble County, and a few square miles in the southeastern part to Summit Township. The Ohio River & Western Railroad crosses the southern part, following South Fork of Wills Creek and thence going up a tributary to the village of Summerfield in Noble County. Calais (pronounced kay'liss), the only village in Seneca Township, is situated near the north edge in the broad flood plain of Seneca Fork. That stream partakes of the characteristics of all branches of Wills Creek and other tributary streams of the Muskingum River system in that it is a sluggish muddy stream of low gradient. In fact, the gradient is so slight that disastrous floods are common, and nearly every year Calais village is flooded and for this reason the population has decreased more than half during recent years. The number of people in 1920 was 49, as compared with 114 in 1900. The census of 1920 shows the population of the entire township to be 933.

The hills bordering the broad valleys of this township rise in moderately steep slopes that have for the most part been cleared of timber and planted to tobacco, which is one of the principal crops. Landslides are so prevalent, however, that in a few years after removal of the woods large hillside tracts begin to creep during rainy seasons, and the result is great scars and a hummocky surface of little use except for grazing. The relief, or local range in elevation, for the township is a little less than 500 feet, the lowest valley being 840 feet above sea level and the highest summits on the ridges 1,250 to 1,300 feet.

GEOLOGIC SECTION.

At first inspection the rocks of Seneca Township would seem to be a monotonous jumble of clay, shale, and limestone with a few beds of sandstone. It is true that coal beds are almost lacking and that the other strata composing the geologic section have a certain similarity. But on closer examination it is found that most of these beds have individual character and can be correlated with similar strata in more or less remote areas. This is true in particular of certain limestone beds which are not only persistent throughout the Summerfield quadrangle, but northeastward beyond Ohio River into West Virginia and Pennsylvania. The columnar sequence of strata exposed in Seneca Township is illustrated by the following section measured near Calais:

Geologic section, in descending order, of strata near Calais.

	Feet.
Shale and sandstone beds, unmeasured.	
Coal blossom, Waynesburg.	
Shale	7
Clay, greenish gray	5
Sandstone, shaly to thick bedded	54
Coal blossom, Uniontown.	
Clay shale with a number of limestone beds	88
Clay, olive-green	6
Clay shale and limestone	13
Coal blossom, Meigs Creek.	
Sandstone, shaly	28
Limestone, Fishpot, with black streak above; position of Lower Meigs Creek coal	3
Clay, shale	25
Shale, carbonaceous with dark shaly limestone below; position of Pomeroy coal	2
Shale, sandy	25
Clay, carbonaceous; position of Pittsburgh coal	1
Limestone, bluish with clay shale and nodular limestone below	20
Limestone, Lower Pittsburgh, in several thick beds	6
Clay and limestone nodules, grading down into shale and sandy beds.	

The scarcity of prominent sandstone members in Seneca Township is manifested in the type of topography, which differs from that of Malaga Township, to the east, in being much less rugged. The hills, it is true, are steep, but their terraced slopes have a covering of soil and turf through which project only a few of the limestone beds, which crop out in rows of bleached boulders that are conspicuous even from a distance.

MINERAL RESOURCES.

Oil and gas have been found in Seneca Township in small quantities only, coal is almost lacking, and other mineral products with the exception of limestone are scarce. Therefore this township must

count as its chief mineral resource the soil, which compares very favorably with that of the richest agricultural communities in eastern Ohio.

COAL.

The only coal bed of possible value is the Meigs Creek, and its extent in workable thickness (1½ to 2 feet) is limited to the southern part of the township. The coal is a mere blossom in the vicinity of Calais. To the south, where seen on a road in sec. 16 (locality 53), on the south side of the valley, the bed is 10 inches thick. At Ethel station, in the southwest corner of the township (locality 50), the bed is 2 feet thick where exposed on the road leading up the hill to the east. At the township line, in the southwest corner of sec. 13 (locality 51), it is 1 foot 2 inches thick.

The position of the Pittsburgh coal bed, which is so valuable to the east in parts of Belmont and Monroe counties, is marked in this township by an inconspicuous black shale about 100 feet below the Meigs Creek coal. About 20 feet lower is the prominent Lower Pittsburgh limestone, which can be traced continuously from Calais downstream to the mouth of Beaver Creek and up that valley beyond Batesville to Temperanceville, where the Pittsburgh coal is 4 to 5 feet thick.

LIMESTONE.

Seneca Township is abundantly supplied with beds of limestone accessible for use on the roads. Nevertheless not a mile of pike has been built, and the roads rank among the poorest in the region. Several of the limestone members are 4 to 5 feet thick, and their nodular outcrops are easily accessible in almost any ravine.

FRANKLIN TOWNSHIP.

About 7 square miles in the northern part of Franklin Township lies within the Summerfield quadrangle. Clear Fork of Little Muskingum River flows southeastward through the central portion, and along it are exposures of the Meigs Creek coal and associated strata. The valley descends at the rate of about 20 feet to the mile, in close agreement with the dip of the rocks. Therefore the coals maintain about the same position with reference to the valley floor across the township.

The Pittsburgh coal is missing in Franklin Township. Its position is about 100 feet below the Meigs Creek coal, or 50 to 60 feet below the valley of Clear Fork. So far as known the bed has never been recorded in oil-well drillings in this area.

The Meigs Creek coal is most valuable in the southwestern part of the [illegible] in the Macksburg quadrangle, where it is 2 to 3 feet th[illegible] than 2 feet thick on Clear Fork in the northern part

of the township, and little or no attempt to mine it has been made by the farmers. The thickness at Swazey is 8 inches and at the north township line (locality 51), 1 foot 2 inches.

The strata higher than the Meigs Creek coal, although more than 200 feet thick, lack coal beds of any value. The Uniontown and Waynesburg beds are represented here by mere "markers" or impure shaly coal only a few inches thick.

SUMMIT TOWNSHIP.

LOCATION AND SURFACE FEATURES.

The political division designated Summit Township is an irregular-shaped area occupying parts of four townships of the original land survey. One square mile at the south side lies within the Matamoras quadrangle; the greater part is in the Woodsfield quadrangle; and a narrow strip along the west border lies in the Summerfield quadrangle. The Ohio River & Western Railroad extends eastward across the south-central portion, and on it is Lewisville, the only village in the township. The population of Lewisville in 1920 was 230, and that of the township 915.

The central part of the township consists of several divides which separate the waters of northwestward-flowing tributaries of Wills Creek, of the Muskingum River system, from eastward-flowing branches of Sunfish Creek and southward-flowing streams that empty into Little Muskingum River. The railroad follows the principal divide westward from Woodsfield to Lewisville and thence goes down South Fork of Wills Creek for several miles. A few hills near the railroad in the eastern part of the township rise more than 1,300 feet above sea level, but the general elevation of the upland ridges ranges from 1,200 to 1,250 feet. In the valley at the northwest corner of the township the elevation is about 900 feet. The surface of Summit Township is somewhat less rugged than that of the western part of Malaga Township, especially in the approaches to the valleys, owing to the less prominent exposures of certain sandstone beds that are conspicuous to the north.

STRATIGRAPHIC SECTION OF ROCKS AT THE SURFACE.

The thickness of the strata appearing at the surface in Summit Township is about 550 feet, including beds ranging in position from a few feet above the Pittsburgh coal horizon to more than 100 feet above the Washington coal bed, which crops out throughout the eastern part of the township. The succession of strata is illustrated by the following general section, which is compiled from measurements made at a number of places.

Generalized section, in descending order, of strata in Summit Township.

	Feet.
Washington formation:	
Shale, red clay, and thin-bedded sandstone	130
Coal, nonpersistent.	
Shale, clay, or sandstone	25
Coal, Washington	1–2
Clay, and shale	18
Shale, sandy, with beds of shaly sandstone	56
Carbonaceous shale, Waynesburg "A" coal horizon.	
Shale, reddish or gray, with local sandstone beds	53
Monongahela formation:	
Coal, thin, or only carbonaceous shale; position of Waynesburg coal.	
Shale	8
Clay, greenish gray	5
Shale, grading down into sandstone of variable character, coarse grained and massive at north edge of township	48
Coal or black shale, Uniontown, commonly in two parts with 10 feet of shale between, the lower part the more prominent.	
Clay shale, with nodular limestone in lower portion	9
Shale, sandy, or sandstone	25
Clay shale, with thin beds of clayey limestone	60
Clay, olive-green	4
Clay shale, or impure limestone	11
Coal, Meigs Creek, thin.	
Shale, sandy	27
Coal, Lower Meigs Creek	1–2½
Limestone in several layers; upper beds gray, lower ones yellowish	5
Shale, sandy	24
Limestone or limy clay	1
Shale, sandy	27
Shale, black, with dark limestone below	3
Shale, sandy or sandstone	23
Pittsburgh coal horizon; black shale underlain by limestone beds. No outcrop in the township. The coal is missing in the western part of the township but may be of minable thickness in the eastern part.	

Probably the most persistent beds of this section are the Washington coal and the greenish-gray clay below the position of the Waynesburg coal. The green clay a few feet above the Meigs Creek coal is also present in large areas and forms a conspicuous greenish band on the washed hillsides that can hardly be mistaken for any other stratum. Generally sandstone overlies the Uniontown coal, but it is far less massive and prominent than in ravines farther north. The sandstone lying below the Washington coal is shaly at the east edge of the township and of increasing prominence eastward beyond Woodsfield.

STRUCTURE.

The dip of the beds ranges from nearly east to south at a rate of 10 to 30 feet to the mile. There are no well-defined anticlines in Summit or neighboring townships, and the only variations from the regular southeastward dip are a few cross flexures that produce synclinal "embayments" or slight promontory-like "noses" such as that 1 mile west of Lewisville. The direction and degree of dip are represented on Plate XII (in pocket) by contours drawn on the base of the Pittsburgh coal.

MINERAL RESOURCES.

The mineral resources of Summit Township of greatest importance are oil and gas. Coal is present, but the quantity can be proved with certainty only when considerable testing has been done with the diamond drill. Sandstone and limestone occur in moderate amount, the former being found well up in the hills and the latter low in the valleys in the western part of the township.

The principal oil sands are the Big Injun, Keener, Big lime, and Maxton, all of which are productive in the pool at Lewisville and eastward. In fact, several of these sands may be productive in the same well.

COAL.

There are three coal beds of possible value in Summit Township—the Pittsburgh, Lower Meigs Creek, and Washington. (See general section, p. 16.) The Pittsburgh coal is below the surface, and its thickness is in doubt throughout most of the township. The other two are of only moderate value owing to their inferior quality and thinness and for other reasons that are given below.

PITTSBURGH COAL.

The Pittsburgh coal, one of the most valuable beds in Belmont and Monroe counties, is of known value as far west as Malaga and Miltonsburg, but thins abruptly a short distance farther west. In Summit and Center townships the western limit of valuable coal is in doubt. The only information at hand is derived from oil-well records, which are far from reliable. A coal at about the position of the Pittsburgh is recorded eastward from Lewisville and northeastward toward Miltonsburg, but not in the Cooper or Monroefield oil pools. The reasons for questioning the value of the Pittsburgh coal in parts of Center Township, as explained in the description of that township, are also applicable to Summit Township.

On the index map (Pl. V, p. 28) are represented the locations of some of the wells drilled for oil, the records of which mention a coal

bed that is possibly the Pittsburgh. The elevation of each well has been determined and also the elevation of a near-by outcrop of the Washington coal; therefore, at each well the interval between the Washington and Pittsburgh coal beds has been determined. The interval is about 380 feet at Lewisville and increases eastward to about 415 feet near Woodsfield. It is possible that the coal recorded at Lewisville is the Pomeroy, whose position is 25 to 35 feet above the Pittsburgh. In the logs of many of the wells, including practically all wells west of a line extending from Lewisville toward Miltonsburg (shown by the dotted line on the map), drillers have reported "no coal" or "coal marker." In summing up the evidence it is therefore believed unsafe to regard any portion of the Pittsburgh coal in Summit Township as of proved value. There may be a considerable area of valuable coal, but its presence can be demonstrated only by testing with the diamond drill.

MEIGS CREEK AND LOWER MEIGS CREEK COAL.

The Meigs Creek and Lower Meigs Creek coal beds crop out low in the valleys in the western part of the township. Neither is more than 2 feet thick at any place where seen. Their relative positions, as shown in the general section, are about 28 feet apart. The lower coal is invariably underlain by gray limestone, and the interval between it and the upper coal consists of sandstone or sandy shale. About 15 feet above the Meigs Creek coal is a bed of olive-green clay differing in appearance from any other in the region, and this of itself is an unerring guide in the identification of the subjacent coal. The greatest thickness of the Meigs Creek coal was seen on the valley road in the southwest corner of sec. 2 (locality 54, Pl. VI), where it is 1 foot 2 inches thick. The Lower Meigs Creek bed is slightly thicker, ranging from 1½ to 2 feet in sec. 2 and at other places.

WASHINGTON COAL.

The Washington coal bed is confined to the high hills from Lewisville northward and eastward. Its blossom may be seen on nearly every ridge road. At a few places the thickness is evident in natural exposures. Near Lewisville the bed is about 1 foot thick, and has yellow clay below and sandstone above. Near the railroad at the east side of the township the bed is 1½ feet thick and has been mined by stripping at a few places.

SANDSTONE AND LIMESTONE.

Sandstone in massive, bold exposures is far less plentiful in Summit Township than to the north in Malaga Township or to the east in Center Township. The most prominent beds probably occur above Uniontown coal horizon, as in the western part of Malaga Town-

ship, but the beds are, as a rule, even-bedded, shaly layers and, except along the north edge of the township, are not well suited for easy quarrying and of little use for building. There is, however, a supply of sandstone more than adequate for local use in the construction of foundations.

The strata at the surface in the eastern two-thirds of the township include no limestone beds of value, and the same is true of the western portion with the exception of the deeper valleys, whose terraced slopes contain a number of prominent limestone layers interstratified with sandy shale. One of the best layers lies below the Lower Meigs Creek coal. It is 3 to 6 feet thick and sufficiently durable for road metal. The rock has also been burned for agricultural lime. A number of limestone layers are distributed through the section 20 to 70 feet above the Meigs Creek coal, but most of them are clayey and not very durable.

MALAGA TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Malaga Township is an irregular-shaped area covering parts of two townships of the early land survey, including the northwest third of T. 6 N., R. 5 W., and the north two-thirds of T. 6 N., R. 6 W.

Malaga, Miltonsburg, and a part of Jerusalem are the only villages. The population, which in 1920 was 1,106, consists largely of people of German descent whose fathers settled in the region 30 or 40 years ago. Shipping facilities are furnished by the Ohio River & Western Railroad, which crosses the adjoining township at a distance of about 2 miles beyond the south and east township limits. Woodsfield, the principal town on the railroad, is about 7 miles from Miltonsburg and 8 miles from Malaga.

There is no limestone pike within the township. A good road extends from Barnesville, about 17 miles north, to the county line half a mile north of Malaga village. Most of the ridge roads are good because of the generally sandy soil, but most of the valley roads are poor.

The surface of Malaga Township is drained chiefly by southeastward-flowing tributaries of Sunfish Creek, which head in the west-central portion and flow in valleys 100 to 200 feet deep. The western third is deeply channeled by westward-flowing tributaries of Willis Creek, a branch of Tuscarawas River. These streams, almost to their sources, are bordered by steep valley slopes 200 feet high. The bottoms of the valleys are about 900 feet in elevation at the west township line. The least elevation on the eastward-flowing streams is about 1,000 feet.

The surface of the upland is far from level, but there are fairly smooth areas in the southeastern part of the township at about 1,220

feet above sea level, rising northward to about 1,300 feet near Malaga. Whether these level stretches are controlled by resistant underlying rock or are solely the result of erosion is not certain. It is evident, however, that the terraced slopes so prevalent in this region are caused by strata of unequal hardness, the resistant sandstone and sandy shale beds forming steep slopes which flatten to a gentle angle on the outcrops of clay, shale, and coal beds.

GEOLOGIC SECTION.

The rocks that crop out in Malaga Township constitute a columnar section a little more than 400 feet thick. At the base, along Paynes and Seneca forks of Willis Creek, are limestones at the horizon of the Pittsburgh coal, which is too thin to be of value there but is of economic importance where it lies under cover in the eastern part of the township. The floors of valleys on the southeast border of the township consist of rocks overlying the Uniontown coal and more than 200 feet above the Pittsburgh bed. In the hills is the Washington coal with associated limestone beds. The strata that make up the hills vary greatly from place to place. Some coal and limestone beds are persistent throughout entire counties; others may appear and disappear within a distance of only a few miles.

The beds between the coals consist largely of shale and sandstone, which are especially variable, there being all gradations from shale through sandy shale to coarse massive sandstone.

The Washington coal appears in roadside outcrops on most of the ridge roads and is in fact the only coal bed of any value in the hills. The Waynesburg coal fails to appear in workable thickness, and the Uniontown coal is likewise thin except along the creek beds in the extreme southeast corner of the township. The Washington coal is therefore of especial value as a key to geologic exposures because it is so easily recognized.

Chert or flinty rock is far from abundant in the Woodsfield and Summerfield quadrangles, being found at only two places, one of which is in the high hills west of Miltonsburg. The cherty rock occurs in a number of thin beds about 120 feet above the Washington coal. It is only a few feet thick, but is so resistant to weathering that fragments of it are strewn over the surface of the hills. The rock is of a rusty brownish color, flecked with peculiar small white spots of angular outline which are cross sections of crystals.

The beds to a depth of 120 feet below the Washington coal consist of shale, reddish clay, or sandy strata, most of which are not strongly resistant to erosion and form gently receding slopes, slightly terraced. A little lower, however, is the prominent sandstone (correlated with the Gilboy sandstone of West Virginia reports) which overlies

the Uniontown coal bed and is largely accountable for the steep valley slopes in the western part of the township.

STRUCTURE.

The lay or geologic structure of the rocks is illustrated on Plate XII (in pocket) by contours drawn on the base of the Pittsburgh coal. Although that bed is not everywhere present where geologically due, its position is conspicuously marked by underlying limestone beds, and the structural contours are drawn from elevations taken on the limestone. There is a fairly uniform southeasterly dip throughout the township, with a few local irregularities such as the terrace-like flattening at Malaga and the shallow trough extending in a nearly north-south direction east of that village. In the western part of the township there is a flat anticline from which the rocks dip to the southwest, south, and east.

MINERAL RESOURCES.

The principal mineral products of Malaga Township are oil and gas, there being more than 120 wells that have produced one or the other of these products. The principal productive oil sands are the Keener and the Big lime. The Berea sand yields oil at a few places.

COAL.

The coals that crop out in Malaga Township are of little value, although the positions of at least six beds of value in other townships are marked by more or less carbonaceous material. These are, in ascending order, the Pittsburgh, Lower Meigs Creek, Meigs Creek, Uniontown, Waynesburg, and Washington.

PITTSBURGH COAL.

Outcropping portion.—The Pittsburgh coal bed, so far as known, is little more than a carbonaceous shale where exposed in the valleys of Seneca Fork, Paynes Fork, and North Fork, in the western part of the township and in Seneca Township to the west. The position of the bed is marked by black shale underlain by limestone and sandy shale. About 20 feet lower is the prominent Lower Pittsburgh limestone, which can be followed in outcrop northward to regions where the Pittsburgh coal is a valuable bed.

The coal lying beneath a heavy sandstone low in the valleys near the west edge of the township is the Lower Meigs Creek coal and not the Pittsburgh bed, although it has been so identified by some observers. This bed has been mined in a small way near the headwaters of Paynes Fork and Seneca Fork of Wills Creek.

Portion under cover.—Under cover the Pittsburgh coal probably exists in valuable thickness throughout the eastern two-thirds of the

township. This is indicated by several core-drill tests and by records of numerous oil wells. The oil-well records, it is true, are of little value as positive evidence of the thickness of a coal bed, but the fact that the coal is noticed by the driller is fair evidence that the bed is several feet thick. The approximate western limit of workable coal, as designated on the index map (Pl. V, p. 28) by a dashed line, extends in a direction slightly east of south from the middle of sec. 24 to the south township line in the western part of sec. 15. Northward the line extends along the west side of Boston to Temperanceville. The coal is reported in the oil wells of the Egger pool, in sec. 15, and also in the coal test on the Williams farm, at the west edge of sec. 18. No record of the coal test on the Miller farm, in the same section, was obtained. No Pittsburgh coal is reported in wells drilled in sec. 21 or westward in the Monroefield pool. The coal is likewise missing in the Cooper pool southeast of Monroefield.

On the index map (Pl. V) are shown by dots the locations of some of the oil wells in the records of which mention is made of the Pittsburgh coal. The presence of the bed south of Miltonsburg in sec. 9 and a portion of sec. 15 seems established.

Records of the strata penetrated in diamond-drill coal test holes on several farms have been furnished by Mr. Edward Christman and are given in part below.

Partial record of core-drill hole No. 23, on Williams farm, sec. 18, Malaga Township.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Shale, carbonaceous, place of Uniontown coal	1	6	29	6
Interval mostly shale and limestone	106		135	6
Shale, carbonaceous, place of Meigs Creek coal		2	135	8
Interval, mostly shale	24	10	160	6
Coal, Lower Meigs Creek	2	3	162	9
Interval, shale, sandstone, and limestone	82	4	245	1
Coal, Pittsburgh	4	7	249	8
Limestone.				

Condensed record of core-drill hole No. 26, on Sloan farm, in the NE. ¼ sec. 17, Malaga Township.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Sandstone, limestone, and clay	119	9	119	9
Waynesburg coal bed:				
Slate and coal		5	....	
Slate, dark	5	1	....	
Slate and coal		3	....	
Shale, dark	1	6	....	
Coal	1	3	....	
Shale, dark	2	3	....	
Slate and coal		6	131	
Limestone, shale, and sandstone	146		277	
Coal marker, Meigs Creek	1	3	278	3
Limestone, shale, and sandstone	83	4	361	7
Coal, Pittsburgh	4	3	365	10
Limestone.				

LOWER MEIGS CREEK COAL.

The Lower Meigs Creek coal, as shown in the record of the core-drill hole on the Williams farm, lies 82 feet above the Pittsburgh bed. Its thickness, 2 feet 3 inches, as recorded there, is similar to that found to the west where seen in outcrop. The bed has locally a thickness of 3 feet, but 2 feet is nearer the average. It has been mined by stripping at a few places. In the valley northwest of Monroefield the coal contains many "soot" bands or "dirt" streaks. The bed is at its best on Paynes and Seneca forks, there being few places elsewhere in eastern Ohio where it is present in minable thickness.

This coal has been recorded in nearly all the oil wells in the Monroefield pool and has been labeled the Pittsburgh by the drillers. Its position, about 325 feet below the Washington coal, which crops out at Monroefield, alone is proof that the bed is too high to be the Pittsburgh, whose position is about 400 feet below the Washington coal as recorded in wells 2 miles east of Monroefield.

MEIGS CREEK COAL.

The Meigs Creek coal normally lies 25 to 35 feet above the Lower Meigs Creek coal. It is thin or lacking on the outcrop in Malaga Township and is likewise of little or no importance to the east under cover. A coal reported 75 to 85 feet above the Pittsburgh in most oil wells is probably the Lower Meigs Creek described above. The usual interval between the Pittsburgh and Meigs Creek coals in this township is 95 to 105 feet.

UNIONTOWN COAL.

The Uniontown coal is represented by black shale on the outcrop in the western part of the township. Over the shale is a thick bed of coarse sandstone. The outcrop in the eastern part of the township is limited to a distance of about 1 mile along the valley of Baker Fork and its tributary Grassy Creek in secs. 27 and 33. The bed is 2 to 3 feet thick and contains a number of shale layers. It has been mined for home use at a number of places. The following measurement made on the D. T. Clark farm (locality 111) is representative.

Section of Uniontown coal on D. T. Clark farm, sec. 27, Malaga Township.

	Ft.	In.
Shale, unmeasured.		
Coal		4
Shale		½
Coal, with earthy bands	1	
Clay, with coal streaks	1	8½
Coal		9½
Clay		5
Coal		10
Shale.		
Thickness of coal bed	5	1½

A few feet above the coal is sandstone ranging from shaly and irregularly bedded to coarse grained and massive. Coal is recorded at the Uniontown horizon in a number of oil wells in the eastern part of the township, but there is little hope that the bed is anywhere more valuable than in the mine on the Clark farm.

WAYNESBURG COAL.

The Waynesburg coal is of little value on its outcrop in Malaga Township. No place was found where the bed has been mined. It is possibly present in workable thickness along the north boundary and is known to be of some value in the adjoining township to the north in Belmont County. In the western part of the township the bed consists of a few inches of shaly coal lying in the midst of sandy shale, with a bed of green clay about 7 feet below. This clay, which is 5 to 8 feet thick, is persistent throughout large areas both where the coal is lacking and where it is of minable thickness.

The Waynesburg coal has been recorded in core-drill hole No. 26, on the Sloan farm, in the NE. ¼ sec. 17, and the measurement is as follows:

Section of Waynesburg coal in core-drill hole on Sloan farm, sec. 17, Malaga Township.

	Ft.	in.
Shale, unmeasured.		
Coal and shale		5
Shale	5	1
Coal and shale		3
Shale	1	6
Coal	1	3

WASHINGTON COAL.

Practically all coal seen in the roadside exposures in the hills near Monroefield, Miltonsburg, and Malaga is the Washington bed. This coal is the most persistent in the entire region but has been utilized very slightly, owing to its inferior quality and small thickness. At Monroefield (locality 92) the bed consists of two layers, the lower 1 foot, 2 inches thick and the upper 8 inches, with 5 inches of clay between. West of Malaga, at locality 90, the bed is about 2 feet thick, and southward beyond Miltonsburg it diminishes to about 1½ feet. The two layers with the middle clay band represent the usual form of the bed.

SANDSTONE AND LIMESTONE.

The principal sandstone beds of Malaga Township lie above the Uniontown coal. They vary considerably in appearance. On Baker Fork, in the southeast corner of the township, the sandstone ranges from a single thick homogeneous coarse-textured layer suitable for quarrying to thin-bedded irregular layers that can have no

use excèpt for road metal. There is also considerable variation in character where the beds crop out in the western part of the township. North of Monroefield, about the headwaters of Paynes Fork, the rock is in massive layers 30 to 40 feet thick that form cliffs and overhanging shelves along the ravines. The appearance of the sandstone on the W. F. Peters farm, in sec. 22, is illustrated by Plate X, *A*. The Catholic Church near Miltonsburg was built of stone quarried on the Peters farm.

The roads of the township have not been piked with limestone, although there is a fair supply of rock that can be obtained without great difficulty. In the central and eastern parts, the only limestone bed of importance lies above the Washington coal. It is 3 to 5 feet thick in the vicinity of Miltonsburg, Malaga, and Jerusalem but of less prominence or lacking near Monorefield and other places in the southern part of the township. The limestone near Miltonsburg consists of several layers of dark-gray color and tough texture which lie 10 feet above the Washington coal.

In the valleys in the western part of the township are numerous limestone beds lying 170 to 400 feet stratigraphically lower than the limestone over the Washington coal. The principal beds are below the Lower Meigs Creek coal and are adequate in quality and quantity for piking roads throughout the township.

SUNSBURY TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Sunsbury Township is an irregular area made up of parts of T. 4 N., R. 4 W., and T. 5 N., R. 5 W. All but two columns of sections on the east side of the township lie within the Woodsfield quadrangle.

The population of Sunsbury Township in 1920 was 1,490. Of this number 555 were attributed to Beallsville, the principal village. The Ohio River & Western Railroad runs northward along the west side and eastward along the north side for 4 miles, thence northeastward across Belmont County to Bellaire, on Ohio River.

Nearly all the waters of Sunsbury township are carried by tributaries of Sunfish Creek which rise near the north edge of the township and flow a little east of south. The principal streams are Death Creek, Piney Fork, East Fork of Piney Fork, and Ackerson Run. The Sunfish Creek drainage basin is separated from that of Captina Creek by an east-west divide which is followed for several miles by the railroad. The upper waters of Piney Fork flow in broad valleys bordered by gentle slopes and low hills, but to the south near the township line there is an abrupt deepening and the valleys narrow to gorges bounded by steep wooded slopes and sandstone cliffs. This change from mild to rugged topography is due to the presence of a prominent sandstone bed 40 to 50 feet thick.

The least elevation is about 860 feet on Piney Fork. The neighboring hills rise to about 1,200 feet, and the general elevation of the upland on the principal divides is 1,250 to 1,300 feet. The greatest elevation is in the northeast corner of the township, where two hilltops rise above 1,400 feet.

GEOLOGIC SECTION.

The rocks that crop out in Sunsbury Township resemble those of Malaga Township in that they contain only one coal bed of any value—the Washington. The strata exposed have a thickness of nearly 500 feet, and the horizons of several coals below the Washington are included, but no coal of workable thickness is known. The township is underlain, however, by the Pittsburgh coal bed, which is several hundred feet below the surface throughout the township. The stratigraphic sequence of the outcropping strata is illustrated by the following generalized section:

Generalized section in descending order, of strata outcropping in Sunsbury Township.

	Feet.
Washington formation:	
Clay, shale, and sandy beds to hilltops	200±
Coal, bony or black shale, seen in northeastern part of township	2
Shale, red clay, and sandstone, variable	100–120
Limestone, present only in northeast quarter of township	3
Shale or shaly sandstone, locally limestone near base	40
Coal, Washington	1–3
Shale, sandy	20–30
Sandstone, exceedingly prominent along Piney Fork and branches; less massive to the west; correlated with Mannington sandstone of West Virginia reports	35–50
Coal or carbonaceous shale position of Waynesburg "A" coal; locally 1 foot thick.	
Shale, sandy, with thin-bedded sandstone and layer of dark limestone near base	60
Shale, carbonaceous, underlain by reddish-brown clay shale.	
Monongahela formation:	
Waynesburg coal	3
Shale, sandy, and sandstone	55
Coal, thin, Uniontown.	
Clay shale grading down into shaly sandstone	18
Limestone, Benwood member, in many layers intercalated with calcareous shale; upper portion exposed in valley of Piney Fork	60±
Covered to Pittsburgh coal	132

The strata overlying the Washington coal comprise a monotonous succession of sandstone, shale, and clay, commonly of red color and with little or no limestone except in the basal portion. To the north,

in Belmont County, there are a number of limestone beds in this part of the geologic column. The Washington coal is exposed at many places on the roads and has been stripped in the ravines. Being almost the only coal bed in the township it serves as an excellent key for determining geologic structure.

Few valleys in eastern Ohio are more picturesque and precipitous than that of Piney Fork, with its sandstone cliffs and wooded slopes. The rugged topography is largely caused by the sandstone lying below the Washington coal. In places this sandstone is at least 50 feet thick, but toward the west it thins and grades into shaly sandstone and shale. Oil drillers call this sandstone the "Mountain sand," and in many well logs it is reported to be 60 feet thick. At its base is a coal bed which is locally 1 foot thick. The limestone beds of the Benwood member are prominently exposed near the mouth of Piney Fork, in Adams Township, where they form a cliff along the valley.

STRUCTURE.

In mapping the geologic structure the elevation of the Washington coal was obtained at many points. The interval between this bed and the Pittsburgh coal in different parts of the township is known through core-drill and oil-well records, and it was only necessary to subtract that amount from the elevation of the Washington coal in order to determine the position of the Pittsburgh at each point. Contour lines were then drawn connecting points of equal elevation, and the result is a contour map of the Pittsburgh coal (Pl. XII, in pocket) which shows the attitude or lay of that bed. The direction of dip varies from east to south and locally southwest. The dip varies from almost nothing near Jerusalem, where there is a structural terrace, to more than 60 feet to the mile in the vicinity of Beallsville.

MINERAL RESOURCES.

Sunsbury Township has produced considerable oil and gas but far less than Malaga Township. The most valuable pools lie in the western and northern parts of the township. The principal productive sands are the Big Lime and Keener. In the vicinity of Beallsville oil is also produced from a shallow sand, probably the Buell Run, although called the Cow Run by drillers. The most recently discovered pool, known as the Schriver, is 3 miles southeast of Beallsville. The product here is largely gas derived from the Berea sand.

The township is poorly supplied with easily accessible coal beds and has only a small amount of limestone for road metal. Sandstone is present in inexhaustible quantity, but there is little demand for it except for foundations.

COAL.

PITTSBURGH COAL.

All of Sunsbury Township is probably underlain by the Pittsburgh coal bed in a thickness of about 5 feet. Its presence has been proved by several core-drill tests near Beallsville and one at the mouth of Piney Fork. It is also recorded in the logs of dozens of wells drilled for oil in various parts of the township. It is reported that in drilling one well near the county line northeast of Beallsville no Pittsburgh coal was found, but this report is not significant in view of the unreliability of the churn drill for testing coal.

The following record of a core-drill hole on the William Tracy farm, in sec. 12, was furnished by Mr. Joe I. Johnson, of Johnstown, Pa. It is of interest because both the Meigs Creek and Lower Meigs Creek coals are present.

Partial section of core-drill hole on Tracy farm (No. 28), sec. 12, Sunsbury Township.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Surface	6		6	
Sandstone	60		66	
Slate	2		68	
Coal, probably Waynesburg	2		70	
Interval, mostly slate and lime	208		278	
Coal, Meigs Creek	2	6	280	6
Interval, sand, sandy shale, and slate	18	6	299	
Coal, Lower Meigs Creek	3		302	
Interval	69		371	
Pittsburgh coal: Coal		10	378	3
Pittsburgh coal: Draw slate	1			
Pittsburgh coal: Coal	5	5		

The Pittsburgh coal has a similar thickness in the test hole on the Daniel Kimpton farm, in sec. 35, where the "roof" coal is 1 foot 3 inches and the lower bench 5 feet thick. The clay between is unusually thick, measuring 4 feet. A thickness of 5 feet of coal is reported in coal-test hole No. 30, drilled in sec. 36, about 2 miles east of Beallsville.

OTHER COAL BEDS.

The Lower Meigs Creek and Meigs Creek coal beds lie 70 and 95 feet, respectively, above the Pittsburgh coal. Both are recorded in the logs of wells drilled at several places in the township but are of only remote prospective value owing to their lack of persistence, thinness, and inferior quality. The two coals are recorded in the log of a diamond-drill test hole on the Tracy farm given above. In coal test No. 32, on the Fleaman farm, at the mouth of Piney Fork, in Adams Township, the Meigs Creek coal is in two benches, the upper 1 foot and the lower 2 feet 6 inches thick, with 1 foot 6 inches of clay between. Both the Meigs Creek and Lower Meigs Creek

coals are recorded in the log of coal test No. 31, on the Daniel Kimpton farm, in sec. 35, which is given below.

The Uniontown coal is probably missing or too thin to be of value throughout the township. It is mined to the south along Sunfish Creek in Adams Township, but to the north, up Piney Fork, it changes to a thin layer of carbonaceous shale. The Waynesburg coal is likewise thin on its outcrop in the southern part of the township. From information obtained in well records it is also seen to be of no importance in the northern part. Another coal 1 to 3 feet thick found about 200 feet above the Meigs Creek coal in the test holes on the Kimpton and Tracy farms is believed to be the Waynesburg "A" coal.

The Washington coal appears in outcrop in various parts of the township and has been stripped by the farmers at many places. Its thickness and position with reference to lower coal beds are illustrated by the following core-drill record:

Partial record of core-drill hole No. 31, on Daniel Kimpton farm, sec. 35, Sunsbury Township.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Coal, Washington	1	6	14	
Interval, mostly sandstone	83		97	
Coal, possibly Waynesburg "A"	1		98	
Interval, mostly shale and lime	213		311	
Coal, Meigs Creek	2	3	313	3
Interval, mostly sandstone	37		350	3
Coal, Lower Meigs Creek	2		352	3
Interval, lime and slate	57	9	410	
Pittsburgh coal: Coal	1	3	420	3
Pittsburgh coal: Clay	4			
Pittsburgh coal: Coal	5			

The Washington coal is probably thickest in the eastern part of the township, as indicated by roadside exposures. At the east side of sec. 16 (locality 93) it is 1 foot thick, in the NW. ¼ sec. 3 (locality 95) 1 foot, and in the SE. ¼ sec. 4 (locality 94) 1 foot 6 inches. In some places farther east the bed consists of two benches each 1 to 2 feet thick, with a bed of clay between.

SANDSTONE AND LIMESTONE.

Sandstone is present in great quantity in Sunsbury Township. There are varieties suited to foundations, building, the manufacture of grindstones, curbstones, and paving. The principal sandstone bed below the Washington coal varies greatly in texture and structure and is believed to be fitted for all the above-named uses at one place or another in the township. Some of the rock is sufficiently durable to be suitable for road metal and could be used in areas far from convenient sources of limestone.

Limestone in quantity sufficient to be an important source of road metal is not plentiful. The principal source is the Benwood member, exposed only in the valley of Piney Fork near the south edge of the township. Only a few of the uppermost beds are at the surface. Farther downstream, near the mouth of Piney Fork, the bed is 40 feet thick. The limestone is in many layers 1 to 2 feet thick interbedded with calcareous clay and shale.

The strata lying above the Benwood limestone are almost devoid of limestone. The one noteworthy layer, about 300 feet higher, lies a few feet above the Washington coal. This limestone is seen in ravines on the county line near Jerusalem and Beallsville and is present east and southeast of Beallsville on Ackerson Run, but disappears farther south. In its most prominent exposures the rock is in one or two layers having a combined thickness of about 3 feet.

CENTER TOWNSHIP.

GENERAL FEATURES.

Center Township, like other political divisions of Monroe County, has an irregular boundary and includes parts of several of the square townships of the early land survey. For this reason the east column of sections bear numbers that are duplicated on the west side of the township. In like manner there is a duplication of section numbers at the north and south sides. Woodsfield, a town of 2,394 inhabitants and the seat of Monroe County, lies near the center of the township on the Ohio River & Western Railroad. In 1920 the population of the township outside of Woodsfield was 1,451. The southern third of Center Township lies within the New Matamoras quadrangle, and the following geologic description does not apply to that part.

The divide between the waters of the eastward-flowing Sunfish Creek and southward-flowing tributaries of Little Muskingum River extends eastward through the south-central part of the township. It is followed by the railroad westward from Woodsfield. The general elevation of this divide is 1,200 feet, but a few hills rise as much as 1,300 feet above sea level. The valleys are cut to depths ranging from 250 to 400 feet below the upland, and most of them are bounded by steep wooded slopes. Sunfish Creek follows an extremely crooked course over a narrow valley floor. At the sweeping bends there are indications of rock terraces at various elevations, which suggest that the valley has at one time been less crooked than the modern intrenched gorge.

GEOLOGIC SECTION.

The stratigraphic succession of strata exposed is represented in part by the following section, which was measured on the Barnesville road at the north edge of Woodsfield.

Geologic section, in descending order, on Barnesville road from Woodsfield.

	Feet.
Washington formation:	
Clay, reddish brown	4
Shale, yellowish brown, sandy in lower portion	15
Sandstone, shaly	9
Shale and red clay	9
Poorly exposed interval	17
Clay, yellowish and red	8
Shale, sandy, grading downward into sandstone	21
Carbonaceous shale, thin.	
Clay	4
Sandy shale	5
Clay	4
Coal, Washington	1½
Clay	3
Shale	6
Clay shale	5
Shale	8
Clay, red	8
Shale, argillaceous, sandy, irregularly bedded	32
Sandstone, coarse, with micaceous laminae. This sandstone, which is correlated with the Mannington sandstone of the West Virginia reports, thickens to more than 40 feet east of Woodsfield and forms the prominent cliffs along Sunfish Creek	7
Shale, dark	5
Coal, thin, Waynesburg "A."	
Shale, dark gray	12
Carbonaceous shale, thin.	
Clay, reddish brown, ferruginous	8
Shale, chocolate-brown	5
Limestone, dark gray	½
Shale, sandy	9
Sandstone	13
Shale, sandy, bluish and brownish	8
Monongahela formation:	
Carbonaceous shale, thin; position of Waynesburg coal.	
Shale, dark	7
Clay, greenish, with nodular iron carbonate concretions	4
Shale, sandy, grading down into shaly sandstone	15
Sandstone	17
Shale, sandy	5
Coal, impure, shaly, Uniontown	1
Shale	2
Sandstone	5
Shale, reddish brown	3
Limestone, bluish, laminated, exposed in creek bed at site of old mill; uppermost beds of Benwood limestone member.	

In the deep valley of Sunfish Creek northeast of Woodsfield limestone beds below those recorded at the base of the above section are at the surface, and their combined thickness at the east edge of the township is more than 40 feet. Beneath the limestone on the banks of the creek in that locality and eastward for a number of miles in Adams Township is cross-bedded sandstone which overlies the Meigs Creek coal.

The sandstone above the Waynesburg "A" coal in massive form is seen at the quarry on Standingstone Creek east of Woodsfield and thence eastward along Sunfish Creek for miles. It is not so conspicuous west of Woodsfield, where it consists of a single layer only 7 feet thick with shale above and below, as shown in the section at the north side of the town. This is only 1½ miles northwest of the quarry, where the principal bed is 28 feet thick and is overlain by 20 feet of thin-bedded sandstone. Farther west and northwest there is shale or shaly sandstone or locally red clay at this horizon. Beds of red clay with nodules of hematite iron ore are not uncommon above the Washington coal.

STRUCTURE.

The strata throughout most of Center Township do not lie flat but dip at the rate of as much as 40 feet to the mile in a southeasterly direction, with local variations. At the east edge of Woodsfield there is a shallow synclinal depression bordered on the southeast by a low arch, east of which the normal southeasterly dip is resumed. Northeast of Woodsfield there is an area of more than 1 square mile where the rocks lie nearly flat. The geologic structure is represented on the map (Pl. XII, in pocket) by contours drawn on the base of the Pittsburgh coal. The position of this bed with reference to the Washington coal and other outcroping strata is known through well records and direct measurements made elsewhere.

Although the strata at and near the surface lie almost parallel to one another, there is a varying interval between any one of these and the several deep sandstones that yield oil and gas. For this reason a special structural map has been prepared for the Berea oil sand.[14]

MINERAL RESOURCES.

Oil and gas, coal, sandstone, and limestone are the principal mineral resources of Center Township. The oil and gas pools, which rank among the most important in Monroe County, derive their products chiefly from the Berea, Keener, and Big lime sands.

[14] U. S. Geol. Survey Bull. 621, Pl. 25, 1916.

COAL.

PITTSBURGH COAL.

Information concerning the thickness and extent of the Pittsburgh coal in Center Township is derived entirely from records of wells drilled for oil and gas. Two core-drill test holes (Nos. 27 and 34) have been drilled in the eastern part of the township, but the records were not obtained. The coal is recorded in the logs of nearly all the hundreds of wells drilled in the northern half of the township, but there are no reliable data as to its thickness. The bed is an excellent key stratum and for this reason is recorded in drilling. The coal at its best, as shown by a number of core-drill tests, averages 4½ to 5½ feet in thickness north and east of Center Township, and it is not improbably of the same thickness in the northeast half of Center Township. The bed is of value in the vicinity of Miltonsburg and Malaga but it thins abruptly a short distance to the west. Farther south, in Center and Summit townships, the extent of the valuable coal is not so conclusively determined. There is difficulty in obtaining reliable information, especially from oil men, owing to a suspicion that such information is to be used in the enforcement of troublesome legislation concerning the method of casing and the plugging of oil wells. Possibly certain other persons wish to promote the sale of coal lands, even though of doubtful value, and therefore willfully misrepresent facts. The value of the Pittsburgh coal in much of Center Township is undetermined, and the operator is advised to carry on careful exploration with the diamond drill before purchasing land.

MEIGS CREEK AND LOWER MEIGS CREEK COALS.

Two coal beds lying 75 and 95 feet, respectively, above the Pittsburgh coal are recorded in oil-well drilling at various places. The name Mapletown is commonly applied by the drillers to one or the other of these coals. The one most commonly noted is probably the Lower Meigs Creek bed, which appears in outcrop to the northwest, in valleys near Monroefield. Neither of these coals is of much prospective value in Center Township.

UNIONTOWN COAL.

The Uniontown coal, lying 170 to 180 feet above the Pittsburgh, is of slight value as a source of fuel in Center Township. It crops out about 120 feet above the valley floor of Sunfish Creek at the east edge of the township but descends westward to a point 1½ miles northwest of Woodsfield, where it lies in the bed of the creek. To the north, up Baker Fork, the outcrop extends into Malaga Township.

The coal at best is characterized by the presence of several shale layers which interfere with its easy mining, and furthermore the bed is subject to considerable change in thickness from place to place. It is too thin to be of value on Standingstone Run and probably on the railroad north of Coats station. The bed is locally split into two parts north of Woodsfield, the lower, a shaly coal 2 to 3 feet thick, being separated from the upper, less valuable bed by 10 feet or more of sandstone containing irregular veinlets of coal.

The thickness and character of the Uniontown coal in different localities is illustrated by the following measurements. The locality numbers are represented on the maps (Pls. VII and XII).

Sections of Uniontown coal in Center Township.

Hillside road on south side of Sunfish Creek, a quarter of a mile east of township line (locality 115)

	Inches.
Shale.	
Coal	8
Shale	3
Coal	6

Ravine exposure near Woodsfield reservoir site, 2 miles north of Woodsfield (locality 110).

	Ft.	in.		Ft.	in.
Shale.			Shale and limestone		8
Coal		7	Coal, bony.		
Shale, sandy, with carbonaceous layers	10		Shale	1	
Coal, impure shaly with iron concretions	1	2	Sandstone.		

Along Baker Fork, in D. T. Clark prospect, just across north township line (locality 111).

	Ft.	in.		Ft.	in.
Shale.			Coal		9½
Coal		4	Clay		5
Shale		½	Coal		10
Coal, with shaly bands	1		Shale.		
Clay with several coal streaks	1	8½	Thickness of coal bed	5	1½

WASHINGTON COAL.

The Washington coal, 170 to 180 feet above the Uniontown, is the only other outcropping coal that has any value in Center Township. Its thickness is rarely more than 2 feet, but the bed is persistent in large areas with a thickness of about 1½ feet. At the railroad crossing a quarter of a mile east of Woodsfield (locality 97, Pl. IX, p. 34) the bed is 1 foot 5 inches thick, with clay above and below. The thickness at the northeast corner of sec. 17 (locality 98), 2½ miles east of Woodsfield, is 1 foot 2 inches. The coal is probably thickest west of Woodsfield and in former years has been extensively stripped and also taken from underground by drift-mining. A thinner coal is commonly found 15 to 25 feet higher.

SANDSTONE.

Sandstone has probably been quarried more extensively in Center Township than in any other part of Monroe County. The principal quarry, on the railroad 1 mile east of Woodsfield, was operated for many years but is now abandoned. (See Pl. XI, *B*.) The quarry face shows a thickness of 28 feet of massive moderately coarse textured rock, with no regular horizontal partings. There are many irregular lines of weakness along which the rock breaks readily. These are produced by flaky plates of dark mica which on weathering change the light bluish-gray color of the rock to a rusty gray-brown. These micaceous bandings do not favor the quarrying of rectangular blocks. Above the quarry is 10 to 20 feet of thin-bedded sandstone that has been stripped as the work of quarrying progressed. The rock is poorly suited for use in building, being insufficiently cemented to withstand weathering. This friable character is manifested by a peculiar pitted surface on the weathered rock. The rock is apparently best suited for use as railroad ballast, rough rubble, and foundations. There is an unlimited quantity along the valley slopes of Sunfish Creek and its tributaries east of Woodsfield. The rock loses its massive character west of Woodsfield.

LIMESTONE.

Center Township is poorly supplied with limestone, and the only beds worthy of consideration as a source of material for road metal lie below the Uniontown coal along Sunfish Creek, in the eastern half of the township. The uppermost layers form pavements in the creek bed on the Barnesville road 1½ miles north of Woodsfield. Eastward downstream lower and lower layers rise above the bottom of the valley. The combined thickness of these and the interbedded shale and clay is about 30 feet. Some of the layers are argillaceous and not sufficiently durable for use as road metal, but the quantity of good material available is considerable.

ADAMS TOWNSHIP.

LOCATION AND SURFACE FEATURES.

Less than half of Adams Township lies within the Woodsfield quadrangle, the remainder being in the New Matamoras, New Martinsville, and Clarington quadrangles, which adjoin the Woodsfield quadrangle on the south, southeast, and east respectively. The township is made up of parts of four square townships of the original land survey. The population for 1920, as given by the Census Bureau, was 683. The only village within the area is Cameron, at the east edge, in the valley of Sunfish Creek. There is no railroad within the

township but sooner or later a line will reach this area for the exploitation of the Pittsburgh coal. Presumably the route followed will be the valley of Sunfish Creek. The Ohio River & Western Railroad is a short distance west of the township, but with its present route can never be of importance as a carrier of coal because of the many steep grades.

The surface of Adams Township is channeled into rugged relief by Sunfish Creek and its tributaries, which flow in valleys bordered by precipitous rocky slopes 400 feet high. The valley floor is about 700 feet above sea level at the east edge of the township and about 800 feet at the west edge. A few hills are more than 1,300 feet in elevation, but in general the ridges range from 1,200 to 1,250 feet. The gradient of Sunfish Creek, like that of most tributaries of the Ohio in this region, is considerable, and in much of its course the stream flows on bedrock. The steep slopes are largely caused by a prominent bed of sandstone.

GEOLOGIC SECTION.

The strata that crop out in the portion of Adams Township within the Woodsfield quadrangle range from about the horizon of the Meigs Creek coal upward to beds about 100 feet above the Washington coal. The Pittsburgh coal is 100 feet or more below the surface in the valley of Sunfish Creek. Its position at the mouth of Piney Creek, together with that of other strata penetrated in a core-drill hole, is shown by the following record furnished by Mr. D. A. Elvin.

Record of core-drill hole No. 32, on John W. Fleahman farm, sec. 31, Adams Township.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Surface	10		10	
Shale	3		13	
Sandstone	15		28	
Shale	5		33	
Coal, Meigs Creek:				
Coal	1		34	
Shale, gray	1	6	35	6
Coal	2	6	38	
Fireclay	1		39	
Limestone	7		46	
Sandstone	2		48	
Shale, sandy	1		49	
Shale	5		54	
Limestone	2		56	
Shale	1		57	
Sandstone	9		66	
Shale, green	4		70	
Shale, dark	2		72	
Shale, red	3		75	
Shale, green	13		88	
Limestone	1		89	
Shale, limy	11		100	
Sandstone	30		130	
Slate	2	7	132	7
Coal, Pittsburgh	4	4	136	11
Fire clay		6	137	5

The elevation of the Pittsburgh coal in this hole is 638 feet above sea level. The elevation of the Washington coal, as calculated from determinations at outcrops on three sides, is 1,070 feet, giving 432 feet as the interval between the Pittsburgh and Washington coals, which is about 30 feet greater than that at the Belmont County line 5 miles farther north.

The general character of the strata that crop out in Adams Township is illustrated by the following section, compiled from measurements made at several places in the township. The lowest beds are the same as those at the top of core-drill hole No. 32, given above.

Generalized section, in descending order, of strata outcropping in Adams Township.

	Feet.
Washington formation:	
Sandstone, shale, and red clay, with one or more layers of nodular hematite	200
Shale, and shaly sandstone, with beds of clay Coal thin. Clay, brittle, greenish gray, grading down into shale	26
Coal, Washington	1–2
Clay and shale	15
Sandstone; forms prominent cliffs along Sunfish Valley; correlated with Mannington sandstone of West Virginia reports.	58
Coal, Waynesburg "A," thin.	
Shale, sandy, with sandstone layers	23
Limestone, dark gray	½
Shale, sandy	29
Monongahela formation:	
Shale, black; position of Waynesburg coal	½
Shale, sandy, grading down into sandstone	52
Coal, Uniontown, mined on Sunfish Creek	2–3
Shale, grading down into sandstone	35
Limestone, Benwood member, in many layers interbedded with calcareous clay and shale	60
Shale and sandstone, exposed low in valley of Sunfish Creek.	25

STRUCTURE.

The dip in the western half of Adams Township is in general east to southeast at a rate ranging from 15 to 40 feet to the mile. On the whole the eastward dip of the strata is similar to the grade of Sunfish Creek, and the same strata are exposed in the valley across the township. The method of preparation of the structural map (Pl. XII, in pocket) is described on page 23.

MINERAL RESOURCES.

The principal mineral resource of Adams Township is coal, there being two valuable beds—the Pittsburgh, which lies 100 feet or more below the surface and is of great value, and the Uniontown, which

crops out along the valleys, thus affording a convenient source of fuel for the farmers. Oil and gas have not been discovered in large quantities, but the township has not yet been thoroughly tested. A few wells derive gas from the Berea sand in the Schriver pool in the northern part, and small quantities of oil have been found in the Keener sand in sec. 5.

COAL.

PITTSBURGH COAL.

It is probable that all of Adams Township is underlain by the Pittsburgh coal bed in minable thickness. As found in several core-drill records its thickness ranges from 4 to 5 feet, and the bed is recorded in the drilling of oil wells. In the test hole on the John W. Fleahman farm (No. 32), at the mouth of Piney Fork, in sec. 31, the coal is 4 feet 4 inches thick. The complete record is given on page 148. A coal test hole was drilled in the SW. ¼ sec. 36, but no record was obtained.

MEIGS CREEK COAL.

Little is known concerning the Meigs Creek coal aside from information furnished in the record of core-drill hole No. 32, at the mouth of Piney Fork (see p. 148), in which the coal bed has the following parts, from top to bottom: Coal, 1 foot; shale, 1 foot 6 inches; coal, 2 feet 6 inches. The bed is recorded in the logs of a few oil wells, but its thickness is not evident.

UNIONTOWN COAL.

The Uniontown coal bed has been opened at a number of places on Sunfish Creek. It is as a rule divided into several parts by layers of shale and is high in ash, as shown by the analysis of a sample taken in the Charles Mobley mine (locality 113, Pl. VII), in sec. 31 (analysis 20259, p. 40). The measurement made in the Mobley mine is given on page 47.

Sections of Uniontown coal in Adams Township.

Roadside exposure in sec. 6 (locality 115).

	Ft.	in.
Coal		8
Shale		3
Coal		6
	1	5

Prospect on Willis farm, sec. 30 (locality 114).

	Ft.	in.
Shale.		
Coal	2	
Coal, bony		5
Shale.		
	2	5

Prospect on Pasco farm, sec. 30 (locality 116).

	Ft.	in.
Shale.		
Coal	1	10½
Coal, bony		6
Clay shale		7
Coal		10
Shale.		
Thickness of bed	3	9½

In addition to being divided into a number of layers by shale bands, the Uniontown coal varies considerably in thickness and is probably reduced to a thin carbonaceous layer in places—for example, up Piney Fork beyond the forks in sec. 2.

WASHINGTON COAL.

The Washington coal lies about 185 feet above the Uniontown coal bed. About halfway between the two is the position of the Waynesburg coal, but there is no coal at that horizon throughout the portion of Adams Township within the Woodsfield quadrangle. The Washington coal ranges from about 10 inches to 2 feet in thickness, and its "blossom" is seen at many places in the township. Here and there the coal has been stripped by the farmers, but so far as known it has not been mined from underground workings. The greatest thickness observed is in the northern part of the township, in secs. 26 and 32, where the bed is about 2 feet thick. Another coal bed, 16 to 24 feet higher, is locally several inches thick and may be mistaken for the Washington.

SANDSTONE AND LIMESTONE.

Sandstone suitable for a variety of uses is abundant in Adams Township. The principal bed is that above the Waynesburg "A," as shown in the general section on page 16. It is a coarse massive bed 40 to 60 feet thick and produces the precipitous slopes of many of the valleys and the "rock houses" so prevalent in ravines tributary to Sunfish Creek. The rock is sufficiently durable for use in building and for curbstone, foundations, and other purposes, being similar to the same bed where quarried on Standingstone Run near Woodsfield.

Little attempt has been made to improve the roads in Adams Township, although there is a fair supply of limestone that can be obtained with little trouble in the valley of Sunfish Creek. The beds lie below the Uniontown coal and are 40 to 80 feet above the valley floor. Excellent exposures may be seen at the mouth of Piney Fork and also in almost any hillside ravine. The argillaceous limestone beds, each 1 to 2 feet thick, are interbedded with calcareous shale.

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TIN 720 PLATE XII

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DEPARTMENT OF THE INTERIOR
JOHN BARTON PAYNE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 721

GEOLOGY AND PETROLEUM RESOURCES OF NORTHWESTERN KERN COUNTY CALIFORNIA

BY

WALTER A. ENGLISH

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

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CONTENTS.

ILLUSTRATIONS.

GEOLOGY AND PETROLEUM RESOURCES OF NORTHWESTERN KERN COUNTY, CALIFORNIA.

By Walter A. English.

INTRODUCTION.

SCOPE OF REPORT.

The area treated in this report comprises about 200 square miles of hilly and mountainous country and about 350 square miles of the alluvium-covered San Joaquin Valley, in which the Lost Hills, North Belridge or Manel Minor, and Belridge oil fields are situated and in which there appear to be possibilities that other fields may be developed (see fig. 1). The discussion is practically confined to the areal geology and to the possibilities of finding oil in untested areas. Conditions in the developed fields are considered solely as a problem in structural geology, and no attempt is made to present a study of the details of underground conditions. This lack of treatment of the developed fields in detail is due both to the circumstances connected with the preparation of the report and to the writer's belief that the United States Geological Survey's field of greatest usefulness lies rather in the type of work here set forth than in the study of underground conditions of interest to engineers engaged in the work of development and production. The California State Mining Bureau is now making such studies in much more detail and keeping data obtained more nearly up to date than the Geological Survey, under existing conditions, would find possible. The reader is therefore referred for such data to the bureau mentioned.

FIELD WORK.

The field work on which this report is based was done by the writer, assisted by W. S. W. Kew, in the fall of 1916. Approximately two months was spent in the field. The writer originally planned to make this a joint report by himself and R. W. Pack, who was to contribute the discussion of the developed fields. However, owing to the pressure of other work, Mr. Pack's part will probably be much delayed, and it seems best to publish the results available at the present time.

The same field methods were followed as in previous work in California. Copies of the Geological Survey's topographic maps enlarged to a scale of $1\frac{1}{2}$ inches to the mile were used as a base for recording field observations, and locations for plotting geologic

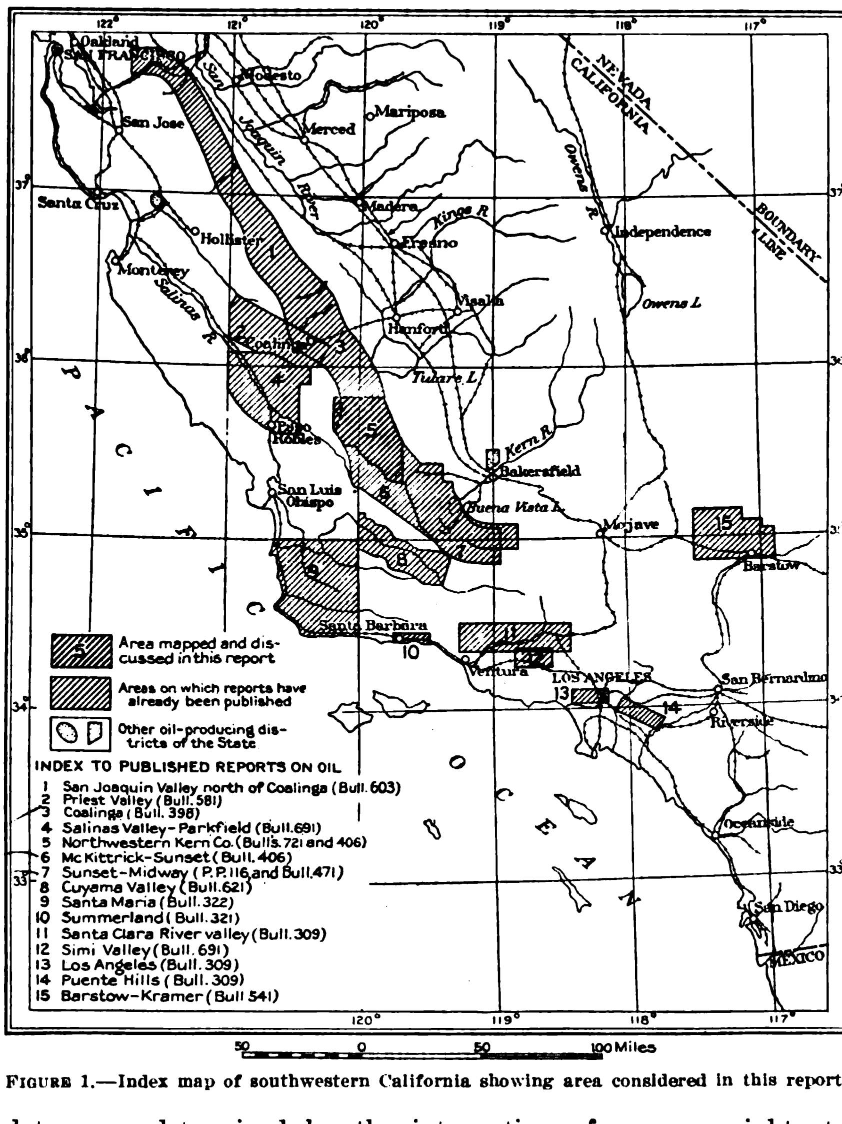

FIGURE 1.—Index map of southwestern California showing area considered in this report.

data were determined by the intersection of compass sights to prominent peaks or other features which it seemed probable had been accurately located by the topographers. Where details of topography seemed to be inaccurately shown, the areal geology as mapped (Pl. I) was adjusted to fit the topographic details only if

no very material change was required. The geologic lines are therefore not in all places shown in their proper relation to the details of topography. No attempt was made to locate any section corners. The accuracy of the geologic lines with respect to section corners therefore depends on the accuracy with which these corners were located by the topographic engineers. Though the land net as shown is in all probability substantially correct, where an accurate tie between the geology and the land lines is desired the relations of the two should be checked.

PREVIOUS PUBLICATIONS.

The following list includes the papers dealing with the geology and petroleum resources of the general region considered in this bulletin that have appeared in recent years:

1894. Watts, W. L., The gas and petroleum yielding formations of the central valley of California: California State Min. Bur. Bull. 3, 100 pp., maps, plates, and figures. Sacramento.

Notes on the topography, geology, and oil resources of the Sunset district are given on pp. 22–37, and on the McKittrick district (called the Buena Vista district in Watts's report) on pp. 41–53; some analyses of water from the region are given on pp. 90 and 91.

1900. Watts, W. L., Oil and gas yielding formations of California: California State Min. Bur. Bull. 19, 236 pp., maps, plates, and figures. Sacramento.

Additional notes to those contained in his former report are given as follows: Geologic sketch of San Joaquin Valley, pp. 106–109; Sunset district, pp. 117–125; McKittrick district, pp. 125–131; Devils Den district, pp. 131 and 132.

1904. Prutzman, P. W., Production and uses of petroleum in California: California State Min. Bur. Bull. 32, 230 pp., maps, plates, figures, and tables. Sacramento.

Maps of the districts and analyses and notes concerning the physical and chemical properties of the oils, their uses, methods of refining, and other useful data are given in this bulletin.

1905. Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., vol. 2, pp. 156–248, pls. 13 to 35, 1 map. San Francisco.

This paper includes a brief discussion of the geology and paleontology of the region along the southwestern side of San Joaquin Valley, including the region from Devils Den to Sunset, together with descriptions and illustrations of many of the fossils found in the Tertiary formations.

1908. Anderson, F. M., A further stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 4th ser., vol. 3, pp. 1–40, San Francisco.

In this paper Mr. Anderson gives a summary of his earlier paper and makes some corrections regarding the age of certain of the formations necessitated by a further study of the region.

1910. Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, Fresno and Kings counties, Calif.: U. S. Geol. Survey Bull. 398, 354 pp., maps, plates, figures, and tables.

This report includes a discussion of the geology and oil resources of the region immediately adjacent on the north to that covered by the present report. Many of the discussions apply to the McKittrick-Sunset region.

1910. Arnold, Ralph, and Johnson, H. R., Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo counties, Calif.: U. S. Geol. Survey Bull. 406.

Describes the geology of northwestern Kern County and gives results of drilling up to date of publication.

1914. McLaughlin, R. P., and Waring, C. A., Petroleum industry of California: California Min. Bur. Bull. 69.

Gives good description of Lost Hills and Belridge fields and map showing location of wells.

1917. Gester, G. C., Geology of a portion of the McKittrick district: California Acad. Sci. Proc., 4th ser., vol. 7, No. 9, pp. 207–227, pls. 33–34.

Points out the unconformable relations of the Maricopa shale and the Etchegoin and Paso Robles ("Tulare") formations, and the bearing of the relations between the Etchegoin and the Paso Robles on the occurrence of oil pools.

1917. McLaughlin, R. P., First Annual Report of the State Oil and Gas Supervisor: California State Min. Bur. Bull. 73.

Chapter 2 gives a description of conditions of water infiltration in the Belridge and Lost Hills fields as well as statistics of wells drilled, etc.

1918. McLaughlin, R. P., Second Annual Report State Oil and Gas Supervisor: California State Min. Bur. Bull. 82.

Gives statistics of wells drilled and a few notes on the progress of study of underground conditions.

1918. McLaughlin, R. P., Third Annual Report State Oil and Gas Supervisor: California State Min. Bur. Bull. 84.

GEOLOGY.

STRATIGRAPHY.

FRANCISCAN FORMATION AND ASSOCIATED IGNEOUS ROCKS (JURASSIC?).

The Franciscan formation, next to the oldest formation that outcrops in the Coast Range, consists of gray and greenish arkosic sandstone, dark and black fissile shale, and thin-bedded chert.[1] This formation has been generally assigned to the Jurassic on the basis of a few fossils found in it and its position beneath the Cretaceous. Basic igneous rocks have been intruded into the sedimentary beds in nearly all places where they are exposed. According to Fairbanks,[2] most of the intrusive rocks are of pre-Cretaceous age, but an in-

[1] A detailed study of the lithology and probable conditions of deposition of the Franciscan formation has recently been published by E. F. Davis, as California Univ. Dept. Geology Pub., vol. 11, Nos. 1 and 3, 1918.

[2] Fairbanks, H. W., U. S. Geol. Survey Geol. Atlas, San Luis folio (No. 101), 1904.

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trusive peridotite (usually altered to serpentine) is younger than the lower part of the Cretaceous. Local contact metamorphism has changed the Franciscan sedimentary rocks into schists that have considerable petrographic interest but that occupy very small areas. Because of the extremely intricate structure and the small size and irregular shape of many of the intrusive masses no attempt is made in this bulletin to differentiate the lithologic types in the Franciscan or to map the Franciscan separate from the associated rocks.

Within the area mapped (Pl. I) the outcrops of Franciscan rocks occupy small areas and are confined to the much-faulted district around the head of Antelope Valley. The fault-bounded strip of Franciscan rocks that extends southward from a locality west of the Antelope pump station consists mostly of peridotite and serpentine but also contains small areas of schist. In the northeastern part of sec. 8, T. 26 S., R. 17 E., is a rocky knob of what appears to be a metadiorite, with a marked schistose structure. A small area of limestone west of the Antelope pump station is described by Arnold and Johnson.[3] In sec. 16 there is an area consisting entirely of serpentine and farther south, close to the faulted anticlinal axis in the Vaqueros, there are several small areas of Franciscan which Arnold and Johnson describe in detail.

No oil is known to occur in Franciscan rocks, and their character and structure make it seem unlikely that oil will be found in them anywhere. Areas within which these rocks outcrop may therefore be safely considered as having no oil possibilities whatever.

CRETACEOUS ROCKS.

The Cretaceous rocks, which consist of dark marine clay shale with lenticular conglomerate and sandstone beds of considerable thickness, were deposited unconformably upon the Franciscan formation. Where the Cretaceous rocks are well exposed in the Coast Ranges, enormous stratigraphic thicknesses have been measured. West of Coalinga a thickness of 19,000 feet of mostly Lower Cretaceous beds is present[4] and north of Coalinga a thickness of 24,000 feet of Upper Cretaceous rocks.[5] The Cretaceous succession is in some areas broken by an unconformity which separates the Lower Cretaceous (Shasta series) from the overlying Upper Cretaceous (Chico formation). Elsewhere, as within the area here described, no unconformity has

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[3] Arnold, Ralph, and Johnson, H. R., Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo counties, Calif.: U. S. Geol. Survey Bull. 406, p. 33, 1910.

[4] Pack, R. W., and English, W. A., Geology and oil prospects of Waltham, Priest, Bitterwater, and Peachtree valleys, Calif.; U. S. Geol. Survey Bull. 581, p. 127, 1915.

[5] Anderson, Robert, and Pack, R. W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, Calif.: U. S. Geol. Survey Bull. 603, p. 37, 1915.

been observed, and the separation, if made at all, must be made on the basis of fossils.

The field work for the present report was confined almost entirely to the areas that contain outcrops of Tertiary rocks that bear some relation to a study of the oil resources of the region. The Cretaceous was therefore only mapped where structural complications bring it to the surface within the areas of Tertiary formations that border the San Joaquin Valley. Outcrops of Cretaceous rocks were examined in a number of areas north of Bitterwater Creek and near the Temblor ranch. Most of Barril Valley is underlain by Cretaceous shale, good exposures of which are seen along the McGovern Gap road. Here, as at other places where the formation was examined, it consists of dark-green clay shale that contains intercalated beds of flaggy sandstone, most of them one-half to two inches thick, which make up perhaps 5 per cent of the stratigraphic thickness. The sandstone breaks up into plates, which weather to a dark reddish brown. These platy fragments, scattered over a surface covered by a clay soil, form reliable evidence of the presence of Cretaceous rocks. The soft clay shale is rather easily eroded, and Barril Valley is largely an erosional feature, determined by the presence of Cretaceous shale. Another area of lithologically similar Cretaceous rocks determines the low topography which extends southeastward from Raven Pass to Bitterwater Valley. The Cretaceous area on the north slope of Shale Hills contains some prominent beds of hard sandstone which weather to a reddish brown. These sandstone beds are 6 inches to 2 feet thick, and each bed is sharply separated from the interbedded shale, which even here makes up 80 per cent of the total thickness.

So far as known, the Cretaceous rocks within this area do not contain oil, except in very small quantities, and no seeps or other evidence of oil have been discovered. The presence of Cretaceous rocks at the surface should therefore discourage prospecting, and if penetrated in a well it should be abandoned, as it must have already passed all probable oil-bearing horizons.

TEJON FORMATION (EOCENE).

The Tejon formation, which unconformably overlies the Cretaceous rocks, is well represented in the central and southern part of the area mapped (Pl. I), where it consists of massive buff sandstone and less prominent dark clay shale. North of Bitterwater Creek it is absent, having been entirely eroded previous to the deposition of the Miocene rocks, which rest directly on the Cretaceous rocks. The massive cavernous-weathering quartzose sandstone is characteristic of the Tejon throughout the southern part of the State, and the

formation was recognized within this area largely from its lithologic character and stratigraphic position.

The Tejon was examined along the McDonald anticline and in the higher hills from Agua Media Creek southward to the Temblor ranch. In the McDonald anticline the Eocene consists of interbedded dark-green shale and light-buff sandstone. Near the top of the section there is a massive yellow sandstone that contains a great many nearly round concretions from 2 to 3 feet in diameter. These concretions are very hard, and as the formation is eroded large numbers of them are left lying on the surface of the ground. The old sheep corral at the McDonald ranch is built of these concretions. A good example of the unconformity between the Tejon and the overlying Miocene beds may be seen along the northern end of the Tejon inlier in the McDonald anticline.

Farther back from the edge of the valley the Tejon is exposed in a continuous outcrop from a locality near Napoleon Spring southward to the Temblor ranch. The characteristic lithology makes this formation easily separable from the adjacent formations, and in many places clearly marked unconformities both at the base and top may be seen.

A paced section of the Tejon, measured along the ridge on the north side of Agua Media Creek, shows it to be approximately 1,800 feet thick, made up as follows:

Section of Tejon formation on north side of Agua Media Creek.

Top of section.	Feet.
Alternate sandstone and shaly sandstone and some shale; the sandstone beds weather to rather prominent craggy outcrops	400
Hard massive cavernous-weathering buff sandstone; contains irregular nodular concretions	100
Alternate sandstone and clay shale, comprising five zones of shale and four of sandstone; the shale is dark green to gray but not as dark as the Cretaceous shale	400
Concretionary zone, comprising mostly sandstone, together with some shale; contains hard round concretions 1 foot to 2 feet in diameter	250
Soft fine yellow shaly sandstone	100
Fine-grained yellow sandstone, shaly sandstone, and shale; the sandstone forms prominent outcrops on both sides of Agua Media Canyon	300
Soft fine-grained sandstone; weathers to a yellow and red soil	275
Base of section.	
	1,825

South of Agua Media Creek the beds shown in the above section are present, and in addition about 1,000 feet of overlying buff sandstone, making a total thickness of 2,800 feet. The Tejon thins

northward from Agua Media Creek. About a mile northeast of Walnut Springs it is only 1,000 feet thick, and a short distance northwest of Napoleon Spring it is entirely overlapped by the beds of the lower Miocene. Farther north, near the mouth of Cedar Canyon, the Tejon again appears as a massive sandstone, which is exposed for a distance of 2 miles along the strike and reaches a thickness of 400 feet.

The Tejon is well developed between Agua Media Creek and Temblor ranch and is composed of material similar to those in the section measured north of Agua Media Creek. Because of the unconformity at the base of the lower Miocene these beds rest on different beds of the Tejon in different places, including massive cavernous-weathering sandstone, nodular sandstone, and shaly beds.

The only fossils found in the Tejon south of Antelope Valley were the following forms from Salt Creek, which, however, are not characteristic:

Fossils from Tejon formation near Salt Creek.

Dentalium sp.?	Shark teeth.
Bryozoa.	Brachiopod.

The age determination rests on the lithologic similarity to the Tejon beds on the north side of Antelope Valley from Point of Rocks northward, where a good Tejon fauna is found near the base of the formation.

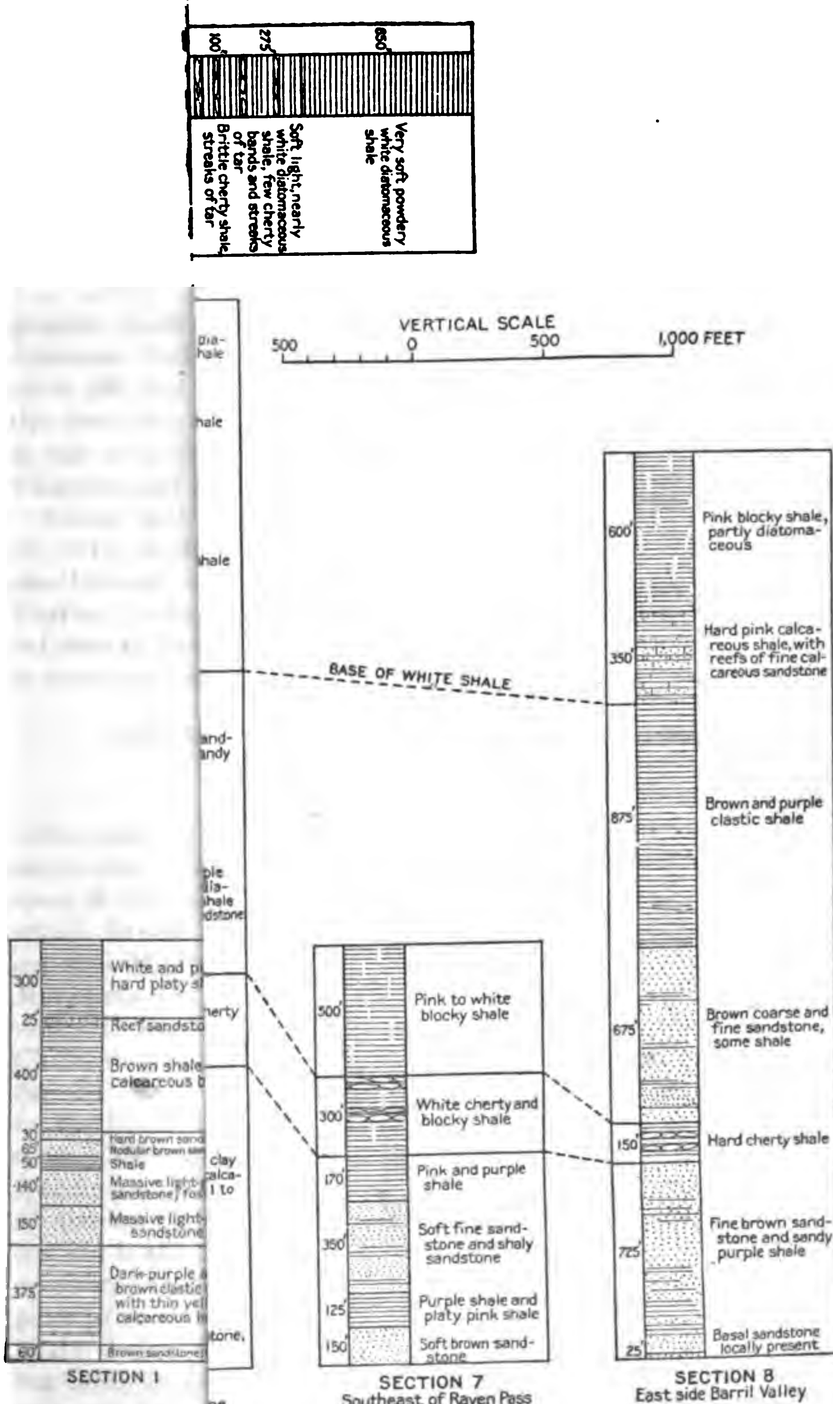
The Tejon is excellently exposed in the vicinity of Point of Rocks, on the north side of Antelope Valley. The writer made only a hasty examination of this area, a detailed description of which may be found elsewhere.[a] The beds consist of nodular, massive, and cavernous-weathering sandstone, similar to that which outcrops in the vicinity of Agua Media Creek. An excellent Tejon fauna was collected from hard calcareous sandstone beds near the base of the formation.

Like the other pre-Miocene formations within this area, the beds of Tejon age in all probability contain no oil. There are no seeps or other evidence of oil on the outcrop, and the absence of any diatomaceous shale in it or in older formations within this area makes the Tejon an unpromising formation in which to look for oil.

OLIGOCENE (?) ROCKS.

Rocks of possible Oligocene age crop out in the outer hills on the north side of Antelope Valley. The writer made only a very hasty examination of the region north of Point of Rocks and has fol-

[a] Arnold, Ralph, and Johnson, H. R., Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo counties, Calif.; U. S. Geol. Survey Bull. 406, pp. 38–39, 1910.



100'
275'
850'
Very soft powdery white diatomaceous shale
Soft light, nearly white diatomaceous shale, few cherty bands and streaks of tar
Brittle cherty shale, streaks of tar
VERTICAL SCALE
500 0 500 1,000 FEET
BASE OF WHITE SHALE
300' White and p[ink] hard platy s[hale]
25' Reef sandsto[ne]
400' Brown shale calcareous b[eds]
30' Hard brown sand[stone]
65' Nodular brown san[dstone]
50' Shale
140' Massive light sandstone; fos[sils]
150' Massive light sandstone
375' Dark purple & brown clastic with thin yel[low] calcareous la[yers]
60' Brown sandstone
SECTION 1
500' Pink to white blocky shale
300' White cherty and blocky shale
170' Pink and purple shale
350' Soft fine sandstone and shaly sandstone
125' Purple shale and platy pink shale
150' Soft brown sandstone
SECTION 7
Southeast of Raven Pass
600' Pink blocky shale, partly diatomaceous
350' Hard pink calcareous shale, with reefs of fine calcareous sandstone
875' Brown and purple clastic shale
675' Brown coarse and fine sandstone, some shale
150' Hard cherty shale
725' Fine brown sandstone and sandy purple shale
25' Basal sandstone locally present
SECTION 8
East side Barril Valley

[...]NG STRIKE.

lowed the mapping of Arnold and Johnson, though with some modifications. According to their description,[7] the Oligocene (?) consists of about 1,800 feet of prevailingly pink and brownish weathering clay shale, at the base of which lies about 100 feet of nonnodular light-gray to buff sandstone inclosing a fossiliferous calcareous reef. The fossils found by them are not diagnostic of any particular horizon, and the tentative correlation of the beds with the Oligocene was based on their position below the reef zone of the Vaqueros. The writer believes that more detailed paleontologic and stratigraphic work may show that the Vaqueros, on the north side of Antelope Valley, which is mapped by Arnold and Johnson as only 15 to 150 feet thick, is really the equivalent of the top reef bed of the sections south of Devilwater Creek, and that the Oligocene (?) is the equivalent of the underlying part of the undifferentiated Vaqueros and Maricopa deposits, as shown in Plate II.

Arnold and Johnson describe an oil spring in sec. 23, T. 25 S., R. 15 E., in the Vaqueros-reef zone, and several shallow wells get a small amount of oil from the underlying shale, a short distance away. Farther north, in the Coalinga district, large amounts of oil are believed to have originated in Oligocene (?) beds, probably, in part at least, equivalent to these.

VAQUEROS SANDSTONE AND MARICOPA SHALE (MIOCENE).

GENERAL CHARACTER.

An apparently continuous series of marine sandstone and diatomaceous shale, containing lower Miocene fossils near the base, forms most of the foothills along the edge of the valley. This succession, which Arnold and Johnson in their report classified as undifferentiated Miocene, Vaqueros sandstone, Monterey shale, and Santa Margarita (?) formation is here treated as a single stratigraphic unit. It reaches a maximum thickness of more than 9,000 feet at Chico Martinez Creek, where a well-exposed section was measured (see Pl. II, sec. 2), and consists of interbedded sandstone and shale in the lower 1,500 feet, overlain by clay shale and diatomaceous shale. Much of the upper part of the shale is nearly white, of light specific gravity, and is made up in considerable part of the skeletons of diatoms and other skeletal fragments of minute organisms. According to the generally accepted theory, the oil found in this region originated in the diatomaceous shale and was formed from the soft parts of small organisms, the skeletons of some of which are present in the shale. The shale was not only the original source of the oil, but sandy beds in the shale formation form reservoirs from which many of the wells in the productive fields draw their supply of oil.

[7] Arnold, Ralph, and Johnson, H. R., op. cit., pp. 40–41.

These formations, therefore, bear a close relation to the oil, and they will be described in considerable detail.

Although the Vaqueros sandstone and the Maricopa shale are well exposed along the entire length of the foothills which border San Joaquin Valley, a nearly complete section is present only between Gould Hill and the mouth of Carneros Canyon. Even here the McKittrick formation rests in marked unconformity on the Maricopa shale, and a considerable thickness of the shale is undoubtedly overlapped and hidden from view by the McKittrick. The thickness of over 9,000 feet now exposed therefore represents a minimum original thickness, and the succession as originally deposited was probably much more than 10,000 feet thick. North and south of this locality the valley alluvium overlaps all the upper part of the series, and the study was necessarily confined to the lower beds.

The remarkable variation in lithology of these lower beds is graphically shown in the sections in Plate II. From Devilwater Creek southeastward a number of lenticular sandy beds are interbedded with the lower 1,200 feet of shale and sandy shale. Some of the zones of sandstones weather out prominently into reefs which may be seen for miles. The principal reef zones have been mapped as sandstone on Plate I. A closer examination shows that even these reef zones contain considerable amounts of interbedded shale and that the intervening shale zones contain less prominent thin sandy beds. The separation into sandstone and shale can not therefore be shown clearly on the geologic map. Above this reef-bed zone lies from 1,200 to 2,500 feet of pink to brown clay shale and diatomaceous shale, in the lower part of which is a prominent zone of hard platy shale and chert. These beds are overlain by light-colored to white shale, mostly diatomaceous, over 4,500 feet thick. The base of this upper shale zone is shown on the geologic map. The line of separation between this white shale and the underlying less diatomaceous shale is not sharp, and where, because of discontinuous outcrop, the line is not actually traceable the horizon shown as the base of the white shale may be wrongly placed, because of lithologic variation in the beds along the strike. In other words, the line shown as the base of the white shale for the area between Temblor Valley and Carneros Spring may not be at the same horizon as the lines shown near the mouth of Agua Media Creek and in Shale Hills. A comparison of the thickness of the measured sections suggests that the line drawn at the base of the white shale for the area south of Carneros Creek indicates a considerably higher horizon than the base of the white shale on Agua Media Creek. Such a correlation would place the base of the upper shale zone about 1,000 feet lower down in the Chico Martinez Creek section, and on the map the line would be at the western base of the

prominent ridge in sec. 3 and of the 1,894-foot hill in sec. 10, instead of along their northeastern flank as shown.

The basal reef-bed zone is even more variable north of Devilwater Creek than south of it. From Devilwater Creek northward to Bitterwater Valley only a single zone of reef beds near the base of the section is present, and it ranges from 100 to 500 feet in thickness. North of Bitterwater Valley the lower sandstone is from 500 to 750 feet thick except in the McDonald anticline. In that fold there is an apparent thickness of nearly 2,000 feet in which sandstone beds are prominent. The structure along this part of the anticline is irregular and the mapping may not be entirely correct, so the apparent thickness may be due to duplication of beds by faults or folds or by the crushing and thickening incident to folding. If, as the writer believes, the thickness given represents the original thickness it is probably due to the sandy beds extending higher in the succession here, but there may be an extreme local thickening of the basal sandy zone, possibly due in part to overlap.

Farther north, on the northwest side of Barril Valley, a thickness of more than 3,000 feet of the lower sandstone was measured, and in this locality it appears that the sandstone beds are equivalent to all the beds below the horizon of the white shale as mapped in the hills east of Barril Valley and farther south.

CORRELATION AND AGE.

The classification of the beds of Vaqueros and later Miocene age has caused more disagreement among geologists than that of almost any other formations in the Coast Range. The reason for the disagreement lies in the fact that the succession of beds differs greatly within short distances and also in the difficulty in correlation by paleontology between the nonadjacent areas in which detailed work has been done. (See Pl. II.)

The beds here described as undifferentiated Vaqueros sandstone and Maricopa shale are believed to be equivalent in age to at least part of the Vaqueros sandstone, Salinas ("Monterey") shale, and Santa Margarita formation; but no unconformities or other basis for a division into these formations are present. Arnold and Johnson, who mapped in detail the area here discussed, divided this succession into four units—undifferentiated Miocene, Vaqueros sandstone, Monterey shale, and Santa Margarita (?) formation. No unconformities are described in their report as occurring between these formations, the separation being based on lithologic character or faunal content. The reasons for not following the classification of Arnold and Johnson may be summarized for each of their unit[s as] follows:

The fauna present in the undifferentiated Miocene beds, though it contains some species which are found in the so-called Oligocene beds of the Mount Diablo region, does not differ materially from the fauna in the overlying sandy beds mapped as Vaqueros by Arnold and Johnson. The overlap of the undifferentiated Miocene by Vaqueros indicated by Arnold and Johnson's mapping was not borne out by the present work. These basal beds and the overlying Vaqueros are lithologically similar and appear to have been deposited during a continuous cycle of deposition. Thus there appears to be no valid faunal, stratigraphic, or structural evidence for the separation of this lower unit within the area considered in this bulletin.

Arnold and Johnson's description of the Vaqueros sandstone does not state its structural relation to the overlying and underlying beds. Apparently no unconformity was found, and it was separated from the overlying "Monterey shale" because of its lithologic character. They say:

> Despite this [complex structure] the Vaqueros in its more intimate characteristics, as of palaeontology, lithology, color, thickness, etc., is quite uniform. It consists nearly everywhere of beds of tawny to brownish medium-grained sandstones, generally containing many fossils, and nearly everywhere calcareous. The beds are almost always resistant, and hence produce a characteristic reef topography, which alone is usually sufficient to distinguish the beds from any others in the region.[a]

This description, if warranted, would be a valid basis for separation. It is, however, not borne out by the writer's work or by Arnold and Johnson's detailed description of the Vaqueros or by their mapping. On their map the Vaqueros unit is used to show reef-like sandstone beds, irrespective of their stratigraphic position. Thus between Napoleon Spring and Temblor ranch there are two Vaqueros reefs, between which is "Monterey shale." Farther south, in the Midway district, a number of other Vaqueros reefs are shown in the "Monterey shale," and some even in the "Santa Margarita (?) shale." Their mapping therefore confirms the writer's conclusion that the lower or Vaqueros sandy zone grades upward into the "Monterey shale" and that there is no definite or even approximate boundary between the two which may be traced for any considerable distance. No unconformity has been found and no fossils have been found in the overlying shaly beds, so that it seems preferable to map the reef beds simply as sandstone phases in the undifferentiated Vaqueros and Maricopa.

The separation between the beds mapped as "Monterey shale" and "Santa Margarita (?) formation" is stated by Arnold and Johnson to be based mainly on the lithologic characters,[b] though they say that

[a] U. S. Geol. Survey Bull. 406, p. 43, 1910.
[b] Idem, pp. 55–56.

the "Santa Margarita" beds are locally unconformable on the "Monterey shale,"[10] and their areal mapping of the west side of Antelope Valley indicates a marked unconformity between the two. The writer has mapped a line at the base of the white shale which corresponds in a general way with the separation described by Arnold and Johnson, though differing materially in its location as mapped from the line at the base of their Santa Margarita (?) formation. No evidence of an unconformity at this horizon was found within the area studied, and the evidence is not regarded as sufficient to prove that this particular line marks the base of the beds equivalent in age to the Santa Margarita formation of the Salinas Valley region.

F. M. Anderson,[11] in his description of this region, has used the names "Temblor formation" for the lower sandy phase and "Monterey shale" for the overlying shale. As he did not publish a map, he was not under the necessity of showing the line of separation between the two formations. He believes that the "Temblor formation" is of the same age as the Vaqueros, but that the name "Temblor" should take precedence because of a supposed lack of definiteness in the original description of the Vaqueros. The name Vaqueros, however, has been adopted by the United States Geological Survey.

J. P. Smith[12] uses the name "Temblor" for the sandy beds at the base of the succession here described, but he believes on paleontologic evidence that they are younger than the Vaqueros sandstone as originally described and represent the time equivalent of the lower part of the Salinas shale ("Monterey shale") of the coast region, where it overlies the typical Vaqueros sandstone.

Thus there is a difference of opinion as to the relative ages of the beds here described and the Vaqueros sandstone and Salinas ("Monterey") shale of the coast region. Arnold's classification would place the basal beds in San Joaquin Valley (Oligocene (?) and undifferentiated Miocene) below the type Vaqueros; F. M. Anderson would have the sandstone formations in the two regions equivalent in age; and J. P. Smith would place the "Temblor formation" above the Vaqueros. The writer's view is that the Vaqueros sandstone in the two areas is roughly equivalent in age, and that during the submergence which began with the deposition of the Vaqueros and culminated with that of the Salinas shale each of many small areas was submerged at a slightly different time from the rest, so that the

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[10] U. S. Geol. Survey Bull. 406, p. 63, 1910.

[11] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, pp. 156–248, 1905; a further stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 4th ser., vol. 3, pp. 1–40, 1908.

[12] Smith, J. P., Geologic range of Miocene invertebrate fossils of California: California Acad. Sci. Proc., vol. 3, pp. 161–182, 1912.

basal beds are not everywhere of the same age. However, the paleontologic work thus far done has not been sufficient to show which areas were first submerged.

LOCAL DETAILS.

In the following descriptions the area mapped is divided into seven districts, within each of which the character of the undifferentiated Vaqueros and Maricopa rocks is fairly uniform. These districts from south to north include (1) the area from McKittrick to the Temblor Ranch oil field, (2) the west side of Temblor Valley, (3) the area from Gould Hill northwestward to Carneros Creek, (4) the area from Carneros Creek to Devilwater Creek, (5) the area from Devilwater Creek to Bitterwater Valley, (6) the area from Bitterwater Valley northward to the head of Antelope Valley, and (7) the north side of Antelope Valley.

M'KITTRICK TO TEMBLOR RANCH OIL FIELD.

Within the area between McKittrick and the Temblor oil field the structure is extremely complicated, so that at most points the areal mapping can not show whether the outcropping beds represent the upper or lower part of the shale. All lithologic variations of shale occur from soft, powdery, poorly bedded white shale to hard, flinty material and chocolate-colored clay shale. In the vicinity of Sheep Springs several zones of shale breccia occur along fault zones. In this locality the harder of the thin beds of shale, one-half to 1 inch thick, are broken into angular fragments which are scattered through a matrix of softer shale. The formation looks like an angular conglomerate and resembles almost exactly certain phases of the McKittrick formation, for which it was apparently mistaken by Arnold and Johnson. On the ridge just south of Sheep Springs lie boulders of this material that have been hardened by local silicification to form a compact chert as hard as any found in the Franciscan formation. In the much faulted shale on the north side of Frazer Valley there are similar outcrops of shale breccia.

WEST SIDE OF TEMBLOR VALLEY.

The monocline along the edge of the hills farther north gives place to complicated structural features, consisting of small eastward-trending folds and faults along the west side of Temblor Valley. The basal 700 feet of Miocene beds exposed in this area is largely composed of sandstone, and these beds are overlain by a similar thickness of pink to chocolate-colored clay and impure diatomaceous shale. A hard calcareous sandstone, which forms the upper half of the sandy beds, weathers to prominent reefs. This reef bed wherever it was examined, both to the west of the Temblor ranch and to the east, where it swings around a small plunging anticline, is about 300

feet thick and consists of dark-brown to nearly white coarse sandstone and calcareous sandstone. The calcareous beds weather most prominently. They have a pitted appearance, and here and there a concretionary nodule stands out in them. Much of the light-colored sandstone is cross-bedded, and an especially good example of cross-bedding is shown in the reef on the north side of the small syncline in the SE. ¼ sec. 23, T. 29 S., R. 20 E. Below this reef bed lie softer sandstone and shale. Toward the south these lower beds are more sandy, and a basal sandstone zone has been mapped. West of Temblor ranch they consist of brown to dark-gray sandstone and shaly sandstone, in which the bedding planes are not very distinct. Northward from the south line of sec. 23 these beds below the prominent reef bed are less sandy and consist largely of dark shale, which in some places contains fossiliferous sandy beds from 5 to 20 feet thick.

GOULD HILL TO AGUA MEDIA CREEK.

Within the area between Gould Hill and Agua Media Creek the section of the Vaqueros and Maricopa formations that is exposed is by far the most complete section that has been measured anywhere within the region. The beds, which dip 45°–70° NE., contain no minor folds and are excellently exposed. The following section is also shown graphically as No. 2 on Plate II:

Section of Vaqueros and Maricopa formations at Chico Martinez Creek.

Top of section.	Feet.
Very soft, light, porous, nearly white diatomaceous shale	650
Soft white diatomaceous shale, containing three or four hard cherty layers 1 to 5 feet thick in which some tar is present	275
Hard nearly white cherty shale, considerably crushed and breaking into small angular fragments whose interstices contain tar and solid bitumen, makes up half the thickness and softer pink shale the other half	100
Medium-indurated pink shale, which breaks into large angular and discoidal fragments, not very fissile	400
Brown sandstone	5
Medium-indurated pink shale, rather uniform in character, containing yellow calcareous beds 6 inches to 1 foot thick at intervals of 20 to 100 feet	1,405
Pink shale, weathers white, like the overlying shale but contains no calcareous beds	650
Pink blocky shale; calcareous beds rare	800
Interbedded soft blocky shale and a harder shale that breaks into thin flakes; calcareous lentils 20 to 50 feet apart	350
Flaky bluish-white shale and softer pink blocky shale, with interbedded calcareous lentils 20 to 40 feet apart. A pit at the top of this shale exposes a 3-inch vein of selenite in the shale; the prismatic crystals are perpendicular to the sides of the vein, which in turn is parallel to the bedding. Several other veins of selenite in the next 100 feet of overlying shale	775

	Feet.
Soft pink blocky shale, which together with all overlying beds is more or less diatomaceous; it forms the base of the upper shale division	175
Gray clastic shale; weathers yellow to pink and contains interbedded layers of hard white platy shale, which cause the beds of this zone to weather to ridges; yellow calcareous beds are numerous	950
Gray clastic shale; weathers to bluish white and purplish brown and breaks into small crumbly fragments; no calcareous beds	400
Soft brownish, purple-weathering clastic shale; contains few calcareous lentils	450
Hard shale zone, comprising hard white platy shale and calcareous shale, interbedded with softer clay shale	300
Soft yellow clay soil, probably derived from clastic shale	225
Hard brown and white sandstone (upper reef)	20
Fine white shaly sandstone	60
Hard sandstone	10
Shale	65
Hard brown sandstone	10
Brown-weathering clastic shale	100
White sandstone, fairly resistant reef	30
Soft purple clastic shale	45
Hard white resistant sandstone; main reef bed	175
Shaly beds comprising purple clastic and slightly diatomaceous shale and soft shaly sandstone	300
Hard calcareous fossiliferous reef	5
Purple clastic shale	60
Soft brown sandstone and sandy shale, containing a few thin beds of hard sandstone	130
	8,920

In the reef-bed zone the lower of the two reefs is by far the most prominent bed. It reaches a maximum thickness of 250 to 300 feet and consists almost entirely of hard gray calcareous sandstone, in which fossil fragments are common. Below this reef are much thinner, less prominent reefs, each of which is traceable for only a short distance. The basal beds carry abundant well-preserved fossils, and a large fauna could undoubtedly be obtained from these beds by persistent collecting, especially in the vicinity of Carneros Springs and farther north, near Agua Media Creek.

The unconformity between the Miocene and the underlying Tejon is very striking in this area. Northwestward from the saddle in the northwest corner of sec. 15, T. 29 S., R. 20 E., the Tejon is seen to be overturned. It dips 70°–90° SW., but the dip changes abruptly to northeast at the base of the Miocene. Along the contact the Miocene rests on different phases of the Tejon, at one place massive sandstone and at other sandy shale and nodular sandstone.

CARNEROS CREEK TO DEVILWATER CREEK.

Within the area between Carneros Creek and Devilwater Creek there are three main reef zones besides a less prominent basal sandstone. The sandstone zones range from 50 to 300 feet in thickness, but the most prominent part of each reef is thinner, usually not over 25 to 50 feet in thickness. The reefs form long, narrow, dark ridges with broad slopes along the dip from which the overlying softer shale has been stripped by erosion. Their appearance is particularly striking near the mouth of Santos Creek, where because of some minor folding and faulting they form a veritable maze. The reef beds are separated by sandy shale and clay shale, the latter generally dark gray when fresh and weathering to purplish brown or dark yellow. Above the reef zone lie beds of dark clay shale including a few hard yellow calcareous lenticular beds, and above this dark shale comes the white shale division. Within the clay shale there is a zone of hard yellow platy shale, which lies from 100 to 500 feet above the upper reef and is 150 to 250 feet thick. Near Carneros Creek this zone is not very prominent and is represented by a 20-foot bed of hard calcareous shale, but to the north this shale becomes thicker and more resistant, and near Devilwater Creek it outcrops even more prominently than the sandstone reef beds themselves.

The separation between the white diatomaceous shale and the underlying clay shale is much more distinct near the mouth of Agua Media Creek than in the area southeast of Carneros Creek. The upper shale is nearly white and mostly hard and cherty, breaking into small angular blocks, some of which are sufficiently silicified to have a resinous luster. The greater silicification of this shale as compared to that in the section along Chico Martinez Creek is probably due to the greater amount of folding and crushing to which it has been subjected. The upper shale in the small area in sec. 13, T. 28 S., R. 19 E., on the northeast side of the syncline is less disturbed and also softer and more porous.

DEVILWATER CREEK TO BITTERWATER VALLEY.

Northward from Devilwater Creek the upper reef beds become much less prominent and grade into sandy shale. The hard cherty zone which overlies the upper reef becomes much more prominent than it is farther south, and a zone of shaly sandstone appears above the cherty zone.

This lack of prominent reef beds is particularly noticeable in the McDonald anticline, in which only the basal 50 feet of the Miocene weathers out prominently. This lower bed is made up of calcareous fossiliferous reefs, each only a few feet thick, separated by shaly sandstone. Where the Vaqueros swings around the axis of the anti-

cline in sec. 31, T. 27 S., R. 19 E., the basal beds contain, besides many large oysters and other Vaqueros fossils, a number of hard round concretions from the underlying Tejon, which are fairly honeycombed with holes made by boring mollusks. Above the hard sandstone lie about 150 feet of softer yellow sandstone, with some interbedded clay shale and these two sandstones make up the sandstone zone as mapped. From the head of Devilwater Creek northwestward a basal zone 500 to 600 feet thick has been mapped as sandstone. A hard sandstone reef from 25 to 100 feet thick, a continuation of the lower reef in the area to the southeast, forms the top of this lower sandstone phase. Below the reef lies brown-weathering clay shale, with which a few reef beds 5 to 20 feet thick are interbedded. The following two sections give an idea of these lower beds:

Section in northeastern part of sec. 34, T. 27 S., R. 18 E.

	Feet.
Hard brown calcareous sandstone	20
Soft brown sandy shale and sandstone, with a few thin reef sandstone beds	400
Massive white quartzose sandstone, in part calcareous	100
Unconformity.	
Cretaceous shale.	

Section on east side of mouth of Cedar Canyon.

	Feet.
Hard brown fossiliferous reef, composed of calcareous sandstone	10
Soft brown sandy shale	150
Hard brown reef, composed of calcareous sandstone, with fossils	20
Soft brown clay shale, containing a few thin beds of sandstone	350
Brown sandstone Agua ss ?	20
Unconformity.	
Massive yellow Tejon sandstone.	

Above the lower sandy zone lies from 1,000 to 1,200 feet of clay shale, in which lenticular concretionary beds of yellow calcareous shale from 6 inches to 2 feet thick are numerous. These beds are well exposed in the southeast flank of the syncline in the Miocene beds. Above the clay shale zone comes 300 to 350 feet of hard platy shale, which forms a series of prominent knobs, trending northwestward from the 2,923-foot hill in sec. 7, T. 28 S., R. 19 E. By means of this hard-shale zone on the two sides of the closely appressed syncline this fold may be traced for 2 miles south of Bitterwater Valley, but farther south the hard shale does not form sufficiently prominent outcrops to be traceable along the east flank of the syncline. The resistance of this shale to erosion is due to the presence of beds 1 inch to 3 inches thick composed of light-yellow hard

platy porcelaneous shale interbedded with an equal amount of softer clay shale. Northeast of the McDonald anticline this hard shale is somewhat different in character. It becomes in this area a more uniform hard white shale, which breaks into small blocky fragments whose surfaces have a resinous luster. Above the hard shale lies a zone of soft brown sandy shale that contains some shaly sandstone. This sandy shale forms a well-defined belt of low topography in the hills south of the mouth of Bitterwater Valley, and the axis of the syncline for about 2 miles south of Bitterwater Valley is formed by these beds. Above the sandy zone lies the white shale division, which is well exposed on the northeast flank of the McDonald anticline, where much of the material is soft and porous, like the upper part of the shale in the section on Chico Martinez Creek. The white shale also outcrops in the axis of the syncline in the high hills southwest of McDonald ranch.

BITTERWATER VALLEY NORTHWARD TO HEAD OF ANTELOPE VALLEY.

The structure in the area north of Bitterwater Valley is considerably more complicated than that farther south, and for this reason it is somewhat difficult to determine the stratigraphic relations between adjacent beds. There is also a puzzling divergence in character between the beds along the northward continuation of the McDonald anticline and those to the northeast, in the outer hills. This difference in lithologic character appears to be particularly striking on a first examination. The Miocene beds, which rest on the Cretaceous on both sides of the valley southeast of Raven Pass, consist in large part of a nearly white blocky diatomaceous shale, in which very little sandstone or clay shale is noticeable, except in the basal sandy zone, which is probably not more than 500 feet thick. In contrast to this succession of beds is that which lies between the McDonald anticline and the syncline to the east, where the 1,500 to 2,000 feet of beds that are exposed along the axis of the anticline include purple clay shale, alternating with hard calcareous reef-forming sandstone beds and softer brown shaly sandstone, and above the lower reef-bed zone a zone of purple clay shale, containing yellow calcareous lentils, at least 1,000 feet thick and considerably thicker if the section along the ridge north of Bitterwater Valley on the east side of the McDonald anticline is not duplicated by faulting or folding. This discrepancy in lithology led Arnold and Johnson to believe that there is an upper white shale (Santa Margarita(?) formation) which overlaps the lower shale and sandstone ("Monterey" and Vaqueros).

After a careful examination the writer came to the conclusion that the basal beds in both areas were deposited at approximately the same time, even though they differ muc[illegible] ter. The tendency of

the beds farther east to be whiter and more diatomaceous is also notable on the two flanks of the McDonald anticline south of Bitterwater Valley. The sandy beds, which overlie clay shale as exposed near Packwoods, do not differ greatly from the beds near the head of Devilwater Creek, where many prominent sandstone reefs are present in the lower 1,500 feet. The same succession of sandstone and soft and hard shale is present in the Shale Hills as in the area south of the mouth of Bitterwater Valley. The lower 500 feet of beds in the Shale Hills consist chiefly of sandstone, though they do not weather to prominent outcrops, and fragments of shale derived from the interbedded hard shale give the soil a shaly appearance. Locally the sandstone is indurated and forms small buttes of a hard calcareous sandstone. Hard sandstone of this type was noted at Shale Point, near the east line of the SE. ¼ sec. 1, T. 27 S., R. 18 E.; about 1,500 feet south of the northwest corner of sec. 12, T. 27 S., R. 18 E.; and about 1,000 feet west of the Twisselman ranch buildings in sec. 14, T. 27 S., R. 18 E. In each of these localities the hard sandstone is traceable into soft sandstone that weathers less conspicuously, the local prominence being due entirely to an exceptional amount of induration. Above the basal zone of sandstone is a medium-indurated white diatomaceous and clayey shale, which ranges from 200 to 600 feet in thickness. The shale weathers to blocky and hackly prismatic fragments and contains interbedded buff calcareous shale lentils. This zone corresponds to the purple clay shale zone elsewhere and is overlain by hard white diatomaceous shale and sandy shale. Thus the same succession is present in the Shale Hills as elsewhere, though the beds as a whole are much lighter in color and more diatomaceous.

Another example of extreme lithologic variation within a short distance is the change in character of the Vaqueros formation and Maricopa shale between the hills east of Barril Valley and the syncline which trends northwest across sec. 8, T. 26 S., R. 17 E. The character of this change is illustrated by the following section and by No. 8 of the graphic sections on Plate II:

Section of Vaqueros sandstone, measured across sec. 6, T. 22 S., R. 17 E., near head of Antelope Valley.

	Feet.
Top of section.	
Buff-weathering quartzose sandstone containing reef-like beds 5 to 20 feet thick	100
Soft shaly sandstone and sandy shale; weathers to yellow loam	1,400
Quartzose buff-weathering sandstone, alternating hard and soft, the hard beds locally forming extremely rugged reef outcrops; contains *Turritella ocoyana* at base	1,800
Shale and sandstone, the shale largely derived from Cretaceous material	300
Base of section.	
	3,600

The lower 1,575 feet of beds in the area east of Barril Valley corresponds to the lower 2,100 feet of mostly massive quartzose sandstone in sec. 6. The next 1,225 feet of prevailingly shaly beds in the area east of Barril Valley corresponds to the 1,500 feet of sandstone and sandy shale in sec. 6. Thus, in a distance of only a few miles a succession of shales that contain a small amount of sandstone changes to massive coarse sandstone and shaly sandstone. Above the 3,600 feet of sandy beds in the syncline lies pink diatomaceous shale, which corresponds with the upper white shale division in the hills that flank the San Joaquin Valley.

NORTH SIDE OF ANTELOPE VALLEY.

The mapping of the north side of Antelope Valley is almost entirely copied from Arnold and Johnson, though with some modifications. According to their mapping, the post-Tejon formations include Oligocene (?), undifferentiated Miocene, Vaqueros, and Santa Margarita (?) formations. These beds are shown in this bulletin (Pl. I) as Oligocene (?) and sandstone and shale phases of the undifferentiated Vaqueros sandstone and Maricopa shale. The undifferentiated Miocene mapped by Arnold and Johnson is included with the overlying Vaqueros and Maricopa shale.

According to Arnold and Johnson, the Vaqueros consists of 15 to 150 feet of calcareous sandstone, much of which is fossiliferous. It is overlain by pink and white, more or less diatomaceous shale in which there is very little interbedded sandstone or sandy shale. The underlying undifferentiated Miocene is not described by them.

SANDSTONE DIKES.

Dikes of sandstone were noted in the shale at two places. A sandstone dike 100 feet wide and several hundred feet long trends northeastward across the top of the hill just east of the center of sec. 5, T. 27 S., R. 18 E., cutting the shale nearly at right angles to the bedding. The dike consists of a hard, somewhat conglomeratic sandstone and is irregularly stained along the joint planes. Three small parallel dikes traverse the west slope of the prominent ridge near the south line of sec. 3, T. 29 S., R. 20 E., on the north side of Chico Martinez Creek. The sand that formed the sandstone in the dikes is supposed to have been squeezed into its present position along faults in the shale while it was still in a plastic condition.

Another peculiar effect of pressure is shown in the area that lies northwest across Carneros Creek from the prominent hill in the NE. ¼ sec. 31, T. 28 S., R. 20 E. In this locality a hard sandstone reef, which dips 80° NE., is exposed in the middle of a succession of clay shale beds which dip only 20°. This hard bed resemb

sandstone dikes in that its sides are not parallel to the bedding in the adjacent shaly beds. This sandstone, however, shows bedding and was evidently forced up through the shales as a rigid mass during the folding of the beds.

RELATION TO PETROLEUM.

The oil found in the fields along the edge of San Joaquin Valley south of Coalinga is believed to have had its origin in the diatomaceous shale of the Vaqueros and Maricopa formations, the wells getting their supply of petroleum from the overlying sandy beds and also from sandstone lenses in the shale. It is therefore necessary to determine whether the shale underlies an area to be prospected and at what depth it would be reached in drilling. Its recognition in well logs as brown or gray shale gives a useful datum for the correlation of strata between wells, though because of the unconformity at the base of the overlying beds the sands within the shale may not be parallel to its plane of contact with the overlying (McKittrick) formation.

McKITTRICK FORMATION (UPPER MIOCENE, PLIOCENE, AND PLEISTOCENE ?).

Overlying the Maricopa shale is a formation of marine and fresh-water sand, clay, and gravel to which the name McKittrick formation was applied by Arnold and Johnson. These beds largely represent the time equivalent of the Paso Robles ("Tulare") formation of the Coalinga area but include some marine beds toward the base that are probably equivalent to part of the Etchegoin formation. These beds of Etchegoin age crop out only in a very small area and were mapped with the overlying beds of Paso Robles age, though, as shown by Gester, there is an unconformity between the Etchegoin and Paso Robles beds in the region immediately adjacent to the southeast.[13] The relation of the Etchegoin to the Paso Robles is of considerable significance in determining the likelihood of obtaining oil in this region, as most of the oil in the developed fields to the south is produced from the Etchegoin formation. The beds described in this bulletin as McKittrick are assumed to be of Paso Robles age unless it is specifically stated otherwise.

The almost entire absence of rocks of Jacalitos and Etchegoin age from the surface within this region and their comparative thinness where they are penetrated in drilling are significant. In the Lost Hills and Belridge fields beds carrying marine fossils of probable Etchegoin age are penetrated in the wells, but their comparative thinness allows the oil sands, which lie directly above the

[13] Gester, G. C., Geology of a portion of the McKittrick district: California Acad. Sci. Proc., 4th ser., vol. 7, No. 4, 1917.

Maricopa shale, to be reached at a relatively shallow depth. If the same stratigraphic thickness of Jacalitos and Etchegoin rocks were present in these fields as is found in Kettleman Hills the oil sands would lie at an unattainable depth. Before any drilling was done the failure to recognize that the stratigraphic succession in these fields might be the same as that exposed in Gould Hill, rather than like that in Kettleman Hills, led geologists to regard the Lost Hills as probably very deep territory. The Etchegoin is likewise thin in the North Belridge field and is apparently not developed to anything like its maximum thickness anywhere in this region. Its presence beneath the outcropping Paso Robles beds adds uncertainty to predictions of drilling depths in untested areas, as its thinness is probably due in part at least to erosion in pre-Paso Robles time, and the amount of erosion may have been entirely different at points comparatively close together. The unconformity must also be considered in comparing the structure in the Paso Robles at the surface with the structure in the oil sands as determined by a study of well logs.

The separation of the McKittrick formation and the overlying terrace beds is in many places difficult because of the lithologic similarity between the two, particularly in areas like the Antelope Hills, where outcrops are poor and the character of the soil is about the only evidence available. In sec. 29, T. 29 S., R. 21 E., an unconformity is present between some flat-lying gravel and boulder beds which cap several hilltops and the underlying McKittrick, and an unconformity is probably present in most places between the McKittrick and the terrace deposits.

The lithologic character of the McKittrick formation is well shown in the hills of the McKittrick Front, on the northeast side of McKittrick Valley, though the numerous small folds make it impossible to establish the sequence of beds for any considerable stratigraphic thickness. The formation as a whole is soft and contains gray clay shale, sandy clay, fine and coarse white, yellow, and brown sandstone, and shale pebble conglomerate. Locally a hard white limestone bed occurs in the clays, and a few of the thinner sandstones are fairly well indurated. Of the lithologic types present the soft gray sandy shale and the fine-grained shaly sandstones are the most abundant and form over 80 per cent of the total thickness of beds exposed. At a number of places the outcropping sands are richly impregnated with oil. The oil is confined to the coarser beds, and two oil sands may be separated by a parting of shale in which there is no evidence of oil.

From Fraser Spring northward to Temblor Valley the McKittrick is poorly exposed and its separation from the terrace gravels is difficult. A line of springs occurs along its contact with the Maricopa shale in sec. 33, T. 29 S., R. 21 E., and this contact, which is not well exposed, may possibly be a fault.

In Gould Hill and to the northwest the exposures of the McKittrick are fair, especially its basal beds, but the structure is complicated by small folds that make it difficult to measure more than fragmentary sections. The basal McKittrick is well exposed in a small gulch that trends northward across the eastern part of the area of Maricopa shale in sec. 7, T. 29 S., R. 21 E. The basal bed is a massive fossiliferous conglomerate that contains shale pebbles in a hard white limy matrix. This bed is about 10 feet thick and is overlain by 30 to 40 feet of soft white and pink sands and shaly sand. Above these beds lie beds of brown and gray clays and sands. Just at the edge of the valley a bed of shale-pebble conglomerate, considerably silicified, forms the crest of several small hills. The basal bed in this section is probably of Etchegoin age. The McKittrick is also well exposed on the west side of the small hill in the SE. ¼ sec. 2, T. 29 S., R. 20 E., just south of Chico Martinez Creek. The basal 50 feet at this place consists of a light-gray porous gravel bed made up of rounded pebbles a quarter of an inch to 2 inches in diameter, of quartzite, slate, and white shale and a very few of granite. This gravel bed is overlain by soft white poorly bedded shale in which are scattered fragments of yellow calcareous shale. All this reworked material has been derived from the Maricopa shale, and this phase of the McKittrick presents nearly the same appearance as poor outcrops of the shale. One point of difference is that on a soil-covered slope underlain by the Maricopa shale the calcareous fragments tend to be most numerous along lines parallel to the beds from which they were derived, whereas in the McKittrick they are scattered at random over the surface. The same succession is traceable northward to sec. 34, where the hill in the south-central part of the section is formed of reworked diatomaceous shale, and the lower beds, which dip 20°, as recorded on the map, are shale-pebble conglomerate.

The low hills that lie mostly in sec. 27 furnish some of the best outcrops of the McKittrick. The dip is 30°–40° NE., and more than 1,500 feet of beds are exposed. Most of the beds are white clay shale, largely made up of reworked material from the Maricopa shale, and these beds give the hills a whiter appearance than the surrounding areas of terrace material. On the southwest slope of the ridge there are several limy sandstone beds, which contain marine (upper Etchegoin?) fossils. Several hundred feet farther east, at the point where the dip of 40° is recorded on the map, there is a conglomerate 5 feet thick composed of well-rounded granitic boulders in a matrix of pure white quartzose sand. Above this conglomerate lie soft gray and white clayey and shaly beds, most of which do not furnish good outcrops.

In both Antelope Hills and Lost Hills the McKittrick formation reaches the surface, but over most of the area it is difficult to deter-

mine whether the brown pebbly soil is derived from the McKittrick or from an overlying terrace formation. In the Antelope Hills most of the surface soil is probably derived from terrace gravels, but a fine powdery white sand, which is exposed in a pit on the Belridge property, in sec. 35, apparently belongs to the McKittrick formation. At the Belridge camp, in the southeastern part of sec. 35, one of the houses is built on a small mound composed of a brown and white speckled sandstone, which belongs either to the McKittrick or more probably to the terrace gravels. The white specks in the sand are hard bits of diatomaceous shale. Sandstone of the same character caps the terrace deposits which form the low hills in sec. 21, T. 28 S., R. 29 E., a few miles to the southwest.

Gray shale of the McKittrick is exposed at a number of points in the northern part of the Lost Hills, where small cuts have been made. Terrace gravels also form the surface over part of the hills, and at most points it is impossible to tell whether the surface soil is derived from underlying McKittrick beds or from the terrace formation. Locally the surface material has been hardened by a superficial deposit of gypsum, and care must be exercised not to mistake this material for the McKittrick.

QUATERNARY SAND AND GRAVEL.

At the end of the period of deposition of the McKittrick formation and during the later part of that period, there was a general folding and uplift of the rocks of this region, and thereafter the history of the Coast Ranges is one of erosion rather than of deposition, so that Quaternary deposits are comparatively thin and insignificant within the area of the recent mountains. The San Joaquin Valley, on the other hand, is supposed to be a geosyncline and to have been the site of deposition of a large quantity of Quaternary gravels. Both the Sierra Nevada and the Coast Ranges were uplifted near the beginning of Quaternary time, and together they are supposed to have furnished the material for a Quaternary formation which has been estimated to have a thickness in the center of the valley of several thousand feet, some estimates being as high as 10,000 feet. Any such thickness of Quaternary deposits would put the oil-bearing beds entirely out of reach of the drill. Despite this supposed thickness in the center of the valley, the Quaternary gravels are only a few feet thick in the Lost Hills, which are topographically rather far out in the valley. These hills, however, might be regarded as a part of the area of uplift rather than of the geosyncline, but the writer is not convinced that there may not be other areas even farther out in the valley in which the thickness of Quaternary gravels is small.

At some time during the Quaternary period a surface that presented less relief than the present surface was established along the

valley slope of the Temblor Range. Gravels were deposited to a thickness of at least 50 feet on this surface, which now lies about 300 feet above the valley level. Only a very few patches of gravel that occupy isolated hilltops have escaped erosion. Other Quaternary deposits, which were laid down when the level of the west side of the valley was slightly higher than at present, form the low hills that lie mostly in secs. 18, 20, and 21, T. 28 S., R. 20 E. These hills are formed of soft brown-weathering sand considerably finer grained than the valley fill now being deposited.

STRUCTURE.

GENERAL FEATURES.

The discussion of the structure of this region may appropriately be divided into two parts—first, the structure of the Diablo and Temblor ranges, in which the Tertiary and older formations outcrop and within which the structure has been worked out in considerable detail, and second, that of the area covered by Quaternary valley fill, within which much of the structure of the underlying Tertiary beds may only be surmised. Within this area covered by the valley fill, if anywhere, future prospecting is likely to disclose the presence of new productive oil pools, and the structure of the hills is chiefly significant with regard to the oil prospects of the region because it furnishes a clue to the conditions beneath the valley floor.

The broad, nearly level surface of the valley alluvium may be regarded much as if it were an extensive lake, concealing the underlying Tertiary formations up to a certain level of elevation, and not as a line marking a separation between two different types of structure. Though the valley is generally supposed to be determined by a geosyncline and the hills by uplift in post-McKittrick time, the edge of the hills does not everywhere coincide with a structural line separating two such major structural features. During late Quaternary time the western limit of the valley fill has not marked a structural line but has steadily extended farther and farther west, its location at any particular geologic time being dependent upon the amount of deposition of Quaternary gravels which had taken place. Thus, early in the Quaternary period the Tertiary beds were probably exposed far out in the present valley, and in the geologic future the Quaternary deposits may extend far up toward the crest of the present Coast Ranges, obscuring much of the structure which may now be seen. The Tertiary structure, however, remains approximately unaltered, and the location of the western limit of valley alluvium depends as much on Quaternary deposition as on Tertiary structure.

STRUCTURE OF DIABLO AND TEMBLOR RANGES.

Most of the smaller structural features within the area mapped are clearly shown on the geologic map (Pl. I) and need not be described in detail. The following descriptions are therefore confined to the larger structural features and to those smaller features that are of particular interest because of their connection with the accumulation of oil or for other reasons.

The hilly and mountainous region between San Joaquin Valley and the sea is known as the southern Coast Ranges. Individual ranges, more or less distinctly separated from the ranges on either side by intervening wide valleys, may be recognized within this region. These ranges and valleys had a structural origin, having been uplifted or depressed to their present relative positions at the end of the McKittrick epoch. That is to say, the ranges owe their present topographic elevation to the uplift, and if the term used to describe an analogous origin of features of drainage may be applied to them they should be called consequent ranges. Many of the component ridges and other features of the present topography are due, however, to differential erosion acting on rocks of differing resistance. Though they are due to uplift, it is hardly correct to say that all the ranges are anticlinal, for the post-McKittrick uplift that formed them was only one of many uplifts that affected the Tertiary beds, and in some places the latest uplift has elevated a previously formed syncline or a block containing complicated folded and faulted structure and thus formed one of the present ranges. Parts of two of these recently uplifted ranges lie within the area mapped. The mountains north of Antelope Valley form the southern terminus of the Diablo Range, and the hills southwest of Antelope Valley are situated on the northeast flank of the Temblor Range.

The lines of geologic structure within these ranges trend northwest and are therefore roughly parallel to the ranges. The individual folds within each range are not, however, exactly parallel to it but trend more nearly west. Some of the individual anticlines have a tendency to extend out into San Joaquin Valley, where they determine low, more or less completely buried groups of hills similar to the ranges to the west but smaller, less intensely folded, and not faulted to any extent. Thus the Lost Hills anticline and its northern continuation in Kettleman Hills and the parallel Kettleman Plains syncline form an eastward repetition of the structural features of the ranges to the west. The folding, however, is less intense, and the formations are younger, indicating a decrease in intensity of both folding and uplift toward the east. The smaller original uplift toward the east has been a considerable factor in determining the edge of the present valley, though, as has been pointed out, it has not

been the only factor, and the edge of the valley does not everywhere follow the lines of this change. As most of the productive oil fields have been developed in the belt of these low folds that parallel the Coast Ranges on the east, the chief aim of the present work is to determine their location and character.

STRUCTURE OF THE AREA INCLUDED IN SAN JOAQUIN VALLEY.

The Quaternary valley fill extends farther west, relative to the structure of the Tertiary rocks, in the region around Antelope Valley than in the region to the north or south. In the Coalinga region, to the north, the Kettleman Hills, which are determined by an anticlinal fold, rise well above the level of the valley. South of the Kettleman Hills, however, the Quaternary deposits have almost completely buried the continuation of this anticline in Lost Hills, as well as the Antelope Hills anticline and the eastward continuation of the McDonald anticline. In Antelope Valley the alluvium extends westward well within the area of folded and faulted beds which are characteristic of the mountainous parts of the Coast Ranges. To the south of this area the low outlying folds in Elk and Buena Vista hills give rise to hills of considerable height above the valley level. The location of the outlying folds that may exist is therefore more difficult to determine in the area here studied than in the areas to the north and south, which, with their better exposures, may be studied as a guide to the type of structure that is present within the valley and that may be expected to occur within this area.

KNOWN ANTICLINES WITHIN THE VALLEY AREA.

Only three main anticlines—the Lost Hills, Antelope Hills, and Belridge—are known to be present within the valley area of northwestern Kern County, and in all three of these anticlines oil has been produced. The drill records are the chief evidence of the existence of two of them.

The presence of the Lost Hills anticline is strongly suggested by the topography, and besides it has been proved to exist by the drill records. The hills consist of a ridge that has a maximum height of 150 feet and is about 8 miles long from northwest to southeast and about a mide wide. The western slope is very gentle, but the eastern slope is steeper and has been dissected to the depth of a hundred feet by the headward erosion of a number of large gullies. The Lost Hills have been so named because, though easily seen from the east, they appear to be lost to one on the west, where the slight eastward rise is hardly apparent to the eye. That the hills are determined by structure is indicated by their straight trend and long and narrow

form, as well as by the presence toward their north end of several low parallel ridges that can hardly be other than the topographic expression of underlying beds that are more resistant to erosion than the rest. Outcrops are rather scarce, and in many places the character and attitude of the beds that crop out is difficult of recognition because of the presence of superficial deposits of gypsum. Several of the outcrops appear to belong to the McKittrick formation, which, however, is difficult to distinguish from Quaternary gravels. A few dips may be seen in the supposed McKittrick formation in the hills, but the measurements of all of them are open to some question. Such dips as were seen are less than 10° E., and no dips on the western flank of the anticline were found. This evidence of itself might only indicate a resistant zone in an eastward-dipping monocline. The most convincing surface evidence of the anticlinal character of the hills is their trend, which is directly in line with the Kettleman Hills anticline distant about 5 miles from their northwest extremity.

The logs of wells in the Lost Hills field show a well-marked anticlinal structure, with dips of 15° on the flanks of the fold, in beds of the McKittrick formation. This dip contrasts with the lower dips of the surface gravels and with the lower slope of the flanks of the hills where they have not been affected by recent erosion. Although several wells have passed into the underlying Maricopa shale, the evidence is not sufficient to determine the structure in the shale, though there may be an anticline in the shale that has considerably steeper dips than those in the overlying McKittrick formation. The Maricopa shale lies beneath the McKittrick at a depth beneath the surface of only 1,000 feet or less, as contrasted with the Kettleman Hills, in which, according to Arnold, there is a thickness of over 5,000 feet of the Jacalitos and the Etchegoin formations between the Paso Robles and the Maricopa shale. This shows that there must be a pronounced rise in the structure of the Maricopa shale between the south end of the Kettleman Hills and the north end of the Lost Hills.

The surface evidence for the existence of an anticline in the Antelope Hills is rather less convincing than is that for the Lost Hills. The Antelope Hills consist of a rather low rise trending from a locality southeast of Shale Point southeastward as far as the North Belridge or Manel Minor oil field. The hills rise to a maximum of about 50 or 75 feet above the valley and at several points are completely traversed by arroyos that lead eastward from the mouths of canyons along the edge of the Diablo Range. The top of the hills is rather flat and does not as strongly suggest a low dome as does that of the Lost Hills. Northwest of Antelope Hills there is an anticline

that is traceable southeastward as far as Shale Point, and presumably this fold continues southeastward beneath the Antelope Hills.

The logs of wells drilled in the North Belridge field have not been studied sufficiently by the writer to determine whether they prove the existence of an anticline. However, the anticlinal theory of the accumulation of oil is so well established as regards the California fields that the presence of oil in this area is of itself pretty fair evidence of the existence of an anticline. The well logs indicate that the structure in the McKittrick formation is low, and that the dips are less than 10°. The wells penetrate a considerable distance into the Maricopa shale, which is reached at a depth of about 700 feet, but its dip and structure are not known.

The Belridge oil field is on an anticline, of which, however, there is no surface evidence such as outcropping beds or surface elevation. The field was located by drilling near a small oil seepage. The following data on structure in this field, as determined from well logs, may be quoted from the State mining bureau:[14]

> The work done in that field shows that the shallow oil lies above the brown shale in a number of sands which are separated by blue shales. It also shows that these sands and shales lie unconformably on the brown shale, and that the contact surface is roughly anticlinal in form. This should not be construed to mean that we have exact knowledge as to the dip and strike of the individual beds of the brown shale, for we have not. The overlying sands and blue shales form a broad, flat anticline over this irregular ridge of brown shale, but only the upper sands are continuous.

The brown shale spoken of here is the Maricopa shale, and the overlying sands belong to the McKittrick formation. The much smaller thickness of the McKittrick formation in this field than that shown in a section from the hills in sec. 27, T. 28 S., R. 20 E., southwestward to the base of the McKittrick, indicates that there is a pronounced anticline beneath the oil field. In all probability the dip of the Maricopa shale in this field is considerably steeper than the dip of the McKittrick. The areal relations suggest that the anticline on which this field is situated is a southeastward continuation of the McDonald anticline.

The North McKittrick Front field may also lie on an anticline which, like the Belridge anticline, has no surface expression, though the well logs available at present do not give sufficient evidence on which to base any conclusions as to the structure. In fact, much of the trouble caused by water in this field resulted from the lack of similarity of the recorded logs of the wells, so that the structural conditions could not be determined, and thus any satisfactory solution of the trouble, such as shutting the water off at a uniform

[14] McLaughlin, R. P., California State Min. Bur. Second Ann. Rept., p. 239, 1918.

stratigraphic position, could not be accomplished. This anticline may be a northwestward continuation of the Elk Hills anticline of the McKittrick field.

PETROLEUM RESOURCES.

DEVELOPED FIELDS.

HISTORICAL SKETCH.

The first productive field to be developed in this region was the Lost Hills field, the first well in which was drilled in 1910. Thereafter the Belridge, Manel Minor (now called the North Belridge),

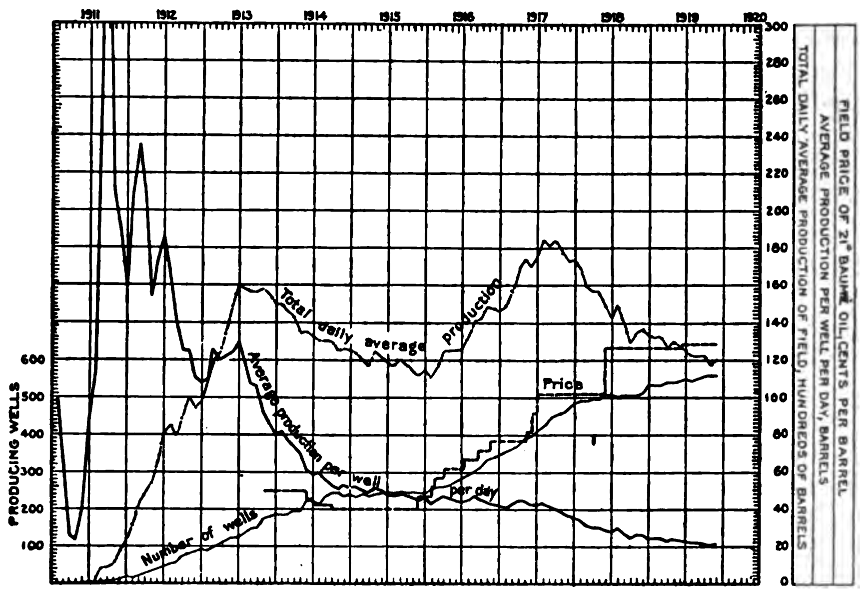

Figure 2.—Diagram showing the production of the Lost Hills, Belridge, Manel Minor (North Belridge), and North McKittrick Front fields, 1910–1919.

and the North McKittrick Front fields were successively developed. The number of producing wells and the combined production of the first three of these fields are shown on the accompanying chart (fig. 2), together with the price of oil. The figures used are those of the Standard Oil Co. of California. The graph of the total production shows four separate trends, representing four phases in the history of these fields. The first period extends from the middle of 1911 to the middle of 1913, during which the daily production increased from a few hundred barrels to about 16,000 barrels a day. This phase represents the initial rapid development of a new field (the Lost Hills) and was accompanied by an increase to a total of

about 125 producing wells. The fall in the average daily production of each well from a maximum of 400 barrels a day during the initial stages of the field to 125 barrels a day, though rapid, was not sufficient to offset the effect of the rapid increase in the number of wells. The second period extends from the middle of 1913 to the end of 1915, during which there was a gradual decline in the total daily production of the fields to 11,500 barrels a day. During the first part of this period the decline resulted from the continued rapid falling off of the average production of the wells, which dropped to 60 barrels a day and which was not offset by the continuation of an active drilling campaign. During the later half of this period the falling off in average production was very much less, because the period of flush production had passed, but the low price of oil caused a practical stagnation in drilling, and the result was a decline in total production. The third period lasted from the beginning of 1916 till September, 1917, during which there was a gradual increase in total production, brought about by the high price of oil, which stimulated drilling, together with the addition of the Belridge and North Belridge areas as productive fields. The fourth period extends from September, 1917, to the present time, during which there has been a decline in production despite the stimulation of high prices. In this period the field enters upon its old age, during which an inevitable decline takes place, and the possible effect on production of high prices is small.

In addition to the fields mentioned, there are two smaller fields—the Devils Den and Temblor Ranch fields—within the area in which the Tertiary formations outcrop. These fields have had some production, though it is very small in comparison to that of the other fields. The Devils Den field contains four or five wells only a couple of hundred feet in depth, which get a barrel or two of oil a day from shaly beds below the hard Vaqueros sandstone reef bed. The Temblor Ranch field draws its oil from approximately the same horizon and is also very shallow territory. However, some of the wells in this field are reported to have produced for a short time in 1911, during the most productive stage of the field, as much as 200 barrels a day of oil that had a specific gravity of about 15° Baumé. Water in considerable volume soon made its appearance in the wells and the production dropped to a maximum of 10 barrels a day in one or two of the best wells. This area was one of the first areas in the State prospected for oil. Wells were drilled near the seeps in this area during the early sixties, when the oil industry was just getting its start in the United States. Even before that time it is reported that the old settlers used the tarry oil from the seeps to grease their wagons.

GEOLOGY.

Devils Den field.—The small amount of oil produced in the Devils Den field comes from a few shallow wells, less than 200 feet deep, in sec. 25, T. 25 S., R. 18 E. The oil comes from a sandy bed in the shale, mapped as Oligocene (?) by Arnold and Johnson, which lies just below the rather prominent Vaqueros reef bed. Possibly where this bed lies at a greater depth it will be more productive.

Lost Hills field.—The productive territory of the Lost Hills field is now completely outlined, and sufficient development has been done to determine the structure with considerable accuracy. Most of the oil comes from the basal beds of the McKittrick formation, directly overlying the Maricopa shale, which is supposed to have been the original source of the oil. The structure is anticlinal and the dips are 10° to 15° on the flanks of the fold in the McKittrick formation. There is considerable irregularity in the McKittrick, sandy beds, shale, and clay being interbedded in lenticular bodies which can not be correlated with certainty in different parts of the field. The oil comes from several sands which extend through a stratigraphic thickness of a couple of hundred feet, stray oil sands being found at different horizons within this zone, though two main sands yield most of the oil. There is a general plunge of the beds to the south and a further increase in depth southeastward, because at the southern end of the field the oil sands lie at a lower horizon than at the northern end of the field. Toward the flanks of the anticline the sands seem to diverge from the underlying shale, so that a bed a certain distance above the shale on the axis of the fold will be farther above the shale on the flanks of the fold. The wells range in depth from 300 feet at the north end of the field to 1,600 feet at the south end, where the oil is replaced by edge water, which likewise limits the field on the flanks of the anticline.

The quality of the oil differs according to the distance above the shale, the lightest oil coming from the beds close to the shale, near the axis of the anticline, and the heavier oil from upper beds and those farther from the axis. In the southern part of the field the oil ranges from 30° to 38° Baumé, whereas farther north oil from 15° to 30° is obtained from the upper sand.

North Belridge field.—The oil in the North Belridge field comes from two horizons both in the Maricopa shale and about 1,500 feet apart. The McKittrick is only about 700 feet thick here, and below it is the Maricopa shale. The upper oil zone is reached at a depth of about 2,500 feet and the lower at about 4,000 feet. Above the lower zone lies a water sand, which has been rather troublesome in some of the wells. The well logs available are insufficient to establish the

anticlinal character of the field. The wells that reach the lower zone are the most productive, and their maximum initial capacity is 1,000 barrels, whereas the capacity of those in the upper zone is only about 50 to 100 barrels a day.

Belridge field.—In the Belridge field, as in the North Belridge field, the productive sands lie at two horizons a considerable distance apart. Most of the oil is derived from sands in the McKittrick formation a short distance above the Maricopa shale. These wells are from 600 to 1,000 feet deep. The sands are lenticular and correlations between wells are rather difficult, so that the details of structure are imperfectly known. It appears that there is a low anticline in the McKittrick formation. Several water sands are apparently interbedded with the oil sands and thus careful mechanical work in drilling the wells is necessary. The lower oil zone, which lies in the Maricopa shale, has been reached in a few wells at a depth of about 3,000 feet. The oil, like that produced elsewhere in the shale series, is light and the initial production is good, but the wells fall off rapidly and water infiltration is troublesome.

Temblor Ranch field.—In the Temblor Ranch field the oil occurs on the south flank of a small anticline at about the same horizon as in the Devils Den field. This horizon is in the lower 2,000 feet of the series, as shown in section 1, Plate I. The limits of the field are defined for the known sand, but lower productive sands may be present. The oil is viscous and its gravity is about 15° Baumé. Only the crest of the fold is productive, and the dips are rather steep, possibly 25° to 30° along the limits of the field.

PROSPECTIVE AREAS.

AREA OCCUPIED BY EXPOSED TERTIARY FORMATIONS.

New fields may be discovered either in the area in which the Tertiary formations of the Diablo Range outcrop or in the area covered by the alluvium of the San Joaquin Valley. The chance of finding new fields appears to be much better in the San Joaquin Valley, even though in the other area the structure is much more perfectly known. In fact, because the knowledge of the structure of the hills is fairly complete, it may be said, with fair assurance of correctness, that there is little chance that fields will be found within that area. The chief reason for the lack of favorable areas to prospect in the hills is that there are no large areas of Maricopa shale properly folded and overlain by sufficient cover to retain any oil which may have been formed in it. The only area of seeming promise in the hills is the region of Temblor Valley, where the eastward-trending anticlines in the Maricopa shale may contain oil at the same horizon as the oil found in the Temblor Ranch field. At

best any such fields would probably be of small extent and small yield. Another possible area is the southeast side of Temblor Valley, where the Maricopa shale is closely folded but where some of the folds might be productive like those in the old McKittrick field, where steeply folded beds on a sharp, overturned anticline yield the oil.

AREA INCLUDED IN SAN JOAQUIN VALLEY.

General features.—The oil pools thus far discovered within the area of the San Joaquin Valley are determined by anticlinal structure, and the existence of other pools is probably dependent on the existence of anticlines other than those now productive. The problem presented is whether there exist any other anticlines which are favorable for testing, and if so to determine if possible their locations. There are no outcrops of Tertiary beds, nor is there other surface evidence to indicate the presence of anticlines other than those now productive, though there is some evidence of the extension of the known folds beyond the areas which have been thoroughly tested. The following discussion therefore relates largely to the possibility of finding new productive folds by drilling more or less at random within the alluvium-covered area of the valley. The only guide to such drilling would be an assumed trend of folds parallel to the other folds of the region and a distance between the folds similar to that between the folds in the areas where they are exposed at the surface or otherwise proved to exist, and an assumed continuation of the known folds beyond the areas where their presence is already proved.

The first point to be considered is the likelihood of the existence of buried folds. It is therefore pertinent to inquire what are the surface features by which the known folds are marked, and what, if any of them, may be expected to mark any other folds that may exist. The surface evidence of the presence of the known folds, which incidentally are all productive of oil, are topographic rise, outcrops of Tertiary formations within an otherwise alluvium-covered area, and the presence of oil seeps. In the following paragraphs it will be demonstrated that all anticlines may not be marked by hills. Likewise, the outcrops of Tertiary formations are not necessarily present, as they only indicate the presence of a former range of hills composed of Tertiary rocks which has been completely buried as a topographic feature but in which the covering over the crest is so shallow that the underlying Tertiary beds outcrop in a few isolated places. The presence of oil seeps is also obviously dependent on the thickness of the beds overlying the oil-bearing horizon and their permeability to the upward-migrating oil, so that if the cover is thick or especially impervious there would be no seeps, even though there was a large amount of oil in the underlying rocks.

In the writer's view, hills are not necessarily present in areas that have anticlinal structure. The correspondence between topographic forms and the forms of the Tertiary anticlines is not as close as has often been stated. Both the Lost Hills and the Antelope Hills anticlines are marked by hills as topographic features, but on the other hand the topographic features in the Belridge and North Belridge fields show little or no indication of the folds. The Lost Hills and the Antelope Hills are remnants of much more prominent hills which were formed during the post-McKittrick period of folding. After their uplift they were eroded to low domelike forms and a small thickness of gravels was deposited over their crests. More recently a slight climatic change has resulted in the cutting of numerous small gullies on the flanks of the otherwise even domes. Except for the recent modification in form they represent mature to old-age topography of an arid cycle. These hills conform to the Tertiary anticlines in location, but their slopes are less steep than the dips in the underlying McKittrick formation. Also the location of the hills may be somewhat shifted from the area directly over the anticlinal axes, because of unequal erosion, as apparently has happened in the Lost Hills.

This conception of the origin of the present topographic features and of their relation to underlying structure is significant and differs markedly from theories previously advanced and widely accepted. Thus Arnold and Johnson apparently hold that the even, domelike form commonly presented was produced by an uplift, which has been followed by no great amount of erosion. They say:

> Seen from a distance, Elk Hills, if the very youthful but very numerous drainage lines be eliminated, must present much the same appearance that it did when formed.[15]

Presumably the term "when formed" refers to the post-McKittrick period of folding, as there is no mention of any later folding believed to have taken place. Also, it is implied, though not explicitly stated, that they not only "present much the same appearance as when formed," but that they are in fact the original hills, practically unaltered by erosion, which were formed by the uplift mentioned. With regard to the Lost Hills they state:[16]

> While the evidence is not absolutely conclusive, the Lost Hills range, which rises about 200 feet above the surrounding plain, is believed to be an anticlinal fold of such recency that its original form, except for the erosional scorings upon the surface, has not been lost.

The writer's view is that the dome of the Elk Hills, like that of the Lost Hills, is an old-age feature of erosion in an arid climate, and that the hills have been subjected to a very large amount of erosion in

[15] U. S. Geol. Survey Bull. 406, p. 76, 1910.
[16] Idem, p. 76.

post-McKittrick time. According to the theory of Arnold and Johnson, there would seem to be very little chance that any post-McKittrick folds could exist without an expression in the topography, and consequently prospecting in areas unmarked by hills would have very little likelihood of success. On the other hand, if we assume that there has been a great deal of erosion since the hills were formed, it may well be that other structural hills have been eroded to such an extent that they have been overridden by the rising level of Quaternary gravel and are consequently no longer represented by any topographic feature whatever.

That the writer's view of the origin of the hills is correct seems to be proved by the lack of correspondence between the geologic structure and topographic form of several ranges of hills. The most striking illustration of this divergence, perhaps, is Kettleman Hills, in the Coalinga area to the north. Kettleman Hills were presumably formed at the same time as Elk Hills and Lost Hills. Kettleman Hills are a low domelike range of hills, slightly modified by recent erosion, essentially similar in form to Elk Hills. However, the geologic structure leaves no possible doubt that there has been a great deal of erosion since their uplift, as the Paso Robles and upper Miocene formations, if restored over the crest of the anticline of the hills, would produce a range of mountains 6,000 or 7,000 feet high, though the hills are at present only as many hundred feet above the surrounding plains. Likewise all along the edge of the Temblor Range, between McKittrick and Sunset, the McKittrick has been affected by a great deal of erosion since the post-McKittrick uplift. It seems hardly likely that there would be any such discrepancy in the amount of erosion in post-McKittrick time as would be necessary if the Elk Hills and Lost Hills are only very slightly modified in form since their original uplift. Though the Elk Hills conform very closely in form to the underlying structure, the dips on the flanks of the hills are rather greater than the slope of the surface. Such agreement in form as there is between topography and structure is probably due to the fact that the beds forming the hills are of fairly uniform hardness throughout, so that in the course of erosion there would be very little tendency for hard beds to form prominent ridges and cause the shape of the hills to depart from that developed by the original uplift. Also, it happens that the structure of the hills would present nearly the same topographic form as that which they would tend to take in the normal course of arid-climate erosion. In the Lost Hills, too, the structure of the McKittrick formation does not parallel the slope of the surface dome but is much steeper, as is proved by the well logs, a line of evidence which was not available at the time that Arnold and Johnson wrote.

If the form of the different ranges of hills is not that developed by the original post-McKittrick uplift, it may still be urged that they were formed by a later uplift, possibly in late Quaternary time, since which they have been only slightly modified by erosion. This hypothesis, too, seems unlikely to the writer, though it is less easily disproved than the one just presented. If such a later uplift had occurred, there would probably be some beds that were deposited in post-McKittrick time but prior to the supposed uplift and that had been tilted by it. Yet no such beds are present. All the Quaternary gravels show only such dips as they probably had when they were deposited. Further, the form of the Lost Hills is not one that would probably have been developed by uplift alone. They form a topographic terrace that has a comparatively steep slope on the east and a very low gravel-covered slope on the west. This form is easily accounted for, and would be expected if a low dome had been overridden by gravel deposits from the west; but a structural terrace of this type would be a rather peculiar form for an uplift to take. Likewise, the low parallel ridges which occur along the length of the hills could hardly have been formed by an uplift unmodified by erosion, though they are easily accounted for as the result of the action of erosion on tilted beds of unequal hardness.

As shown by the preceding discussion, if other folds were formed within the valley area they may have been completely hidden, as far as surface evidence goes, at the present time. But is there any reason to believe that any such folds were actually formed? Are there any buried folds between those now known, or are there others farther out in the valley than those now known? There is no direct evidence bearing on this question. The likelihood of such folds depends on whether the folding which took place was sporadic in character or whether it affected all parts of the area over which it took place without leaving any unfolded areas or "holes" in a region in which the rocks elsewhere were folded, and on how far eastward in the valley the folding extended. It would seem that as the folding was a result of stresses which acted over large areas the folding was continuous over those areas but with diminishing intensity from the center of greatest activity, and that in so far as the beds presented fairly uniform resistance in adjacent areas the folds were probably of about the same steepness and about the same distances apart but in general of decreasing intensity toward the valleys, irrespective of whether the folds are exposed to view or are masked by alluvium. Thus there may well be one or more anticlinal folds in the wide alluvium-covered area between the Lost Hills and the edge of the Temblor Range to the west.

The distance to the east that the folding extended is rather harder to approximate. The Lost Hills anticline marks the eastern limit of the known folds, and on the east side of the valley, in the region of the Kern River oil field, where the Tertiary beds are well exposed, there is a more or less regular low monoclinal dip toward the west. However, on the east side of the valley the Tertiary beds are comparatively thin and rest on a rigid granitic basement, which slopes gradually toward the west under the valley.

The presence of this rigid foundation may have prevented the folding of the Tertiary rocks as they have been folded along the western margin of the valley. The eastern limit of folding very likely lies along a line where the granitic rocks reached such a depth that they were below the zone of activity of the forces causing the folding in this interior area. This line can not be determined from the surface, but it is reasonable to postulate that the forces which caused the folding did not die out abruptly. The folding in the Lost Hills is rather marked, and the absence in that region of so large a thickness of upper Miocene beds (representing the Jacalitos formation and the lower part of the Etchegoin formation) indicates that in the past, at least, there was considerable folding and uplift in a part of the valley far out from the edge of the present Coast Ranges. The writer's opinion therefore is that in Tertiary time San Joaquin Valley was not a geosyncline of unfolded Tertiary beds, but that there were anticlines and synclines of considerable magnitude farther out in the valley than the Lost Hills fold. The possible location of such folds as may exist between or beyond the known folds will be discussed in the following description of separate areas within the region studied.

Area between Lost Hills and Temblor Range.—In the alluvium-covered area some 12 miles wide between the Lost Hills and the edge of the Temblor Range one or more folds may be present. Elsewhere the anticlines out in the valley beyond the edge of the mountains are from 4 to 6 miles apart and are progressively closer together the nearer they are to the edge of the mountains.

The folds in this area are probably not farther apart than elsewhere and thus suggest the presence of an anticline about midway between the Lost Hills anticline and the North Belridge (Manel Minor) anticline.

The presence of an anticline in this area is also suggested by the structure of the Tertiary rocks on the two sides of Antelope Valley. The pre-Miocene formations outcrop much farther to the east on the north side of Antelope Valley than on the south side. The Miocene beds which form Wagonwheel Mountain must therefore swing westward around the axis of a plunging anticline or else be faulted down on the southwest side. A fault with downthrow on the southwest

side has brought Miocene beds into contact with older rocks near the head of Antelope Valley. This fault probably continues a considerable distance to the east beyond the area where it is exposed, probably well into T. 26 S., R. 18 E., but still farther east it may give way to an anticline, like many of the faults which extend eastward into the zone of less intense folding. There is therefore some reason to suspect the presence of an anticline trending southeastward from a point south of Point of Rocks, possibly passing near the 707-foot bench mark in sec. 20, T. 26 S., R. 19 E. Such an anticline should be favorable for the accumulation of oil.

The stratigraphy and structure of the rocks beneath Antelope Valley west of a line drawn north and south through Point of Rocks is probably similar to that of the hills on either side; and if so, the rocks are too much disturbed and the older formations are too extensive for this area to be favorable for prospecting for oil.

Possible continuation of McDonald anticline.—The McDonald anticline is traceable for a distance of about 15 miles in the hills. At its north end the fold has its origin in the much-faulted area west of Barril Valley. From the north line of T. 27 S. it is traceable southeastward as a well-marked steep fold. Just north of Bitterwater Valley there is a southward plunge of 15° to 20°, which brings the shale over the axis. South of Bitterwater Valley the fold is less closely compressed, and the doming brings up the Tejon along the axis. Where the fold approaches the valley alluvium toward the southeast it plunges 8° to 9° southeastward. Beyond the edge of the valley there is no topographic evidence of its continuation. The other folds that are known to extend out into San Joaquin Valley are marked by low hills, so there is some doubt as to whether this fold extends to the southeast or plunges steeply and merges with the monocline that flanks the range south of this region as far as Gould Hill, as does the Ciervo anticline, north of Coalinga,[17] which is well marked in the higher hills but plunges to the southeast and merges with the monocline along the edge of the valley. It has, however, already been pointed out that there is no surface evidence of the probably continuous anticline between Lost Hills and Kettleman Hills, so the lack of surface evidence does not preclude a continuation of the McDonald anticline. The writer believes that this anticline, which is traceable for a considerable distance within the hills, may not terminate at the edge of the valley, but that more likely it continues for at least several miles beneath the Quaternary valley filling. The position of the Belridge oil field suggests that it lies on a continuation of this anticline.

[17] Anderson, Robert, and Pack, R. W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, Calif.: U. S. Geol. Survey Bull. 603, geologic map, 1915.

Gould Hill to the McKittrick Front.—In Gould Hill there are several small folds in the McKittrick formation that trend N. 60° W., and in the north end of the McKittrick Front similar small folds that trend N. 75° W. Between the two areas lies the alluvium-covered Temblor Valley, along the west side of which the folds in the Vaqueros and Maricopa rocks trend nearly east. The probable extension of these folds must be considered. The folds from the west side of the valley may extend eastward between Gould Hill and the Temblor Front or, as appears more likely, they may swing around toward the southeast parallel to the trend of the folds in the McKittrick formation and possibly connect with the folds in the hills northwest of McKittrick. In sec. 8, T. 29 S., R. 20 E., the Maricopa shale strikes nearly east, although the contact at the base of the McKittrick trends N. 30° W., and in the small area in which the shale crops out in secs. 7 and 18, T. 29 S., R. 21 E., its strike is considerably nearer east than that of the surrounding McKittrick formation. It therefore seems likely that the east-west folding was produced previous to the folding that affected the McKittrick formation, and therefore none of the folds in the McKittrick trend east. The small folds in Gould Hill probably continue southeastward beneath the alluvium and are not affected by the folds mapped on the west side of Temblor Valley.

The folds in the hills of the McKittrick Front and on the east flank of Gould Hill are small and close together. Apparently as the folds approach the edge of the main range they become progressively closer together. This close folding probably does not extend far out from the hills, and any folds farther out than the north McKittrick Front are probably wide apart and regular in structure. The writer thinks that possibly the Belridge anticline continues southeastward parallel to the McKittrick Front and that this area would be more likely to contain a well-developed anticline than the area nearer the hills on the west. Another place which seems rather favorable is in the locality where the Lost Hills and North Belridge anticlines would intersect if projected, for if either of the two folds continues with unaltered direction there would be an anticline at that place.

Region east of the Lost Hills anticline.—Though there is no surface evidence of the presence of any folds east of the Lost Hills, the possible value of any discovery in this area makes it advisable in the writer's opinion to test the region far out in the valley by one or more deep wells. Even if an initial well failed to obtain any oil, if the Quaternary deposits were found to be thin the indications would be favorable and would warrant further prospecting. In view of the spacing of folds elsewhere the writer suggests that a belt 6 to 8 miles east of the Lost Hills anticline would include the area in which another anticline is most likely to be present.

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DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 722

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN

1920

BY

A. H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

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MINERAL RESOURCES OF ALASKA, 1920.

By ALFRED H. BROOKS and others.

PREFACE.

By ALFRED H. BROOKS.

This volume is the seventeenth of a series of annual bulletins[1] summarizing the results achieved during the year in the investigation of the mineral resources of Alaska and treating of the mining industry of the Territory, especially of the statistics of mineral production, with the collection of which the Geological Survey is charged by law.

The reports included in this volume are primarily intended to give prompt publication of the more important economic results of the work of the year. The time available for their preparation does not permit full office study of the field notes and specimens, and some of the statements made here may require modification when the study has been completed. Those who are interested in any particular district should therefore procure a copy of the complete report on that district as soon as it is available.

Again, as for many years in the past, the Geological Survey is under great obligation to residents of the Territory for valuable data. Those who have thus aided include the many mine operators who have made reports on production as well as developments. There are still some Alaskan mineral producers who fail to respond to requests for information. Many prospectors, Federal officials, engineers, and officers of banks and transportation and commercial companies have contributed valuable data. It is impracticable to mention by name all who have aided in this work, but it should be stated that without the assistance of these public-spirited citizens the preparation of this report would have been impossible. Special acknowledgments should be made to the Director and other officers of the Mint; the

[1] The preceding volumes in this series are U. S. Geol. Survey Bulls. 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, 642, 662, 692, 712, and 714.

Director and other officers of the United States Bureau of Mines; B. D. Stewart, Territorial mining inspector; the officers of the Alaska customs service; the officers of the Alaskan Engineering Commission; the American Railway Express Co.; Stephen Birch, Kennecott Copper Corporation; Sumner S. Smith, resident engineer of the Alaskan Naval Coal Commission; George Parks, General Land Office; Asa C. Baldwin, of Seattle, Wash.; C. W. Dietzel, of Juneau; Philip Bradley, of Treadwell; George C. Hazelet, of Cordova; J. M. Finnegan, of Kodiak; Paul Buckley, of Unalaska; J. M. Elmer, of Chistochina; F. E. Youngs, of Seward; Sidney Anderson and Milo Kelley, of Anchorage; H. W. Nagley and Edward McConnell, of Talkeetna; Luther C. Hess, the First National Bank, T. H. Deal (postmaster), J. A. Fairborn, and Henry Cook, of Fairbanks; B. J. Everman, of Fox; N. P. Nelson, of Chisana; Charles E. M. Cole and F. E. Phillips, of Jack Wade; Charles Zielke, of Nenana; John B. Mathews, of Hot Springs; George W. Ledger, of Rampart; Oscar Morell, of Deadwood; Alexander Mitchell, of Kantishna; Thomas G. Carter and F. P. Sturrock, of Beaver; H. S. Wanamaker, of Nolan; T. A. Parsons, of Ruby; B. B. Smith and G. W. C. Glass, of Ophir; Harry Madison, of Tolstoi; F. E. Wiseman and R. C. Butler, of Iditarod; D. E. Stubbs and L. Huber, of Aniak; John Haroldson and A. Stecker, of Quinhagak; R. W. J. Reed, of Nome; George P. Stanley, of Kiana; and Louis Lloyd, of Shungnak.

THE ALASKA MINING INDUSTRY IN 1920.

By Alfred H. Brooks.

GENERAL FEATURES.

Though the mining industry of Alaska as a whole suffered a serious depression in 1920, yet the value of the total mineral output was greater than in 1919, chiefly because of the great increase in the production of copper, to be credited largely to the four leading copper mines in the Territory. The value of the total mineral product of Alaska was $19,620,913 in 1919 and $23,303,757 in 1920. The output of the gold placers has decreased, but that of the gold lode mines has been maintained.

During 41 years of mining Alaska has produced minerals to the value of more than $460,000,000, over half of which was produced in the last decade. About 75 per cent of this output has come from small but rich deposits termed "bonanzas." Such deposits can be exploited profitably, even under the most adverse conditions of isolation and transportation, because they yield very large returns on the capital and labor employed.

Bonanza mining, always the first to be developed in a new land, is a most powerful agency in attracting population, in forming communities, and in establishing transportation systems. This mining will continue, for the known bonanza deposits in Alaska have been by no means exhausted, and there is good prospect of finding others. A stable and permanent mining industry can not, however, be founded on the exploitation of only the very rich ore bodies. Permanency must be based on the development of the larger deposits of less unit value. This development depends for its profits not so much on the richness of the ore as on economies made possible by the magnitude of the operations. Large mining operations require regular and cheap transportation; they can not be successful at places served only by the haphazard and expensive means of transportation that are generally available on the frontier. The passage from bonanza mining to a stable and permanent industry takes place in all mineral-bearing regions and has long been under way in the accessible coastal region of Alaska, but the mineral wealth of the interior remains practically untouched except by the bonanza miner.

It will be well to emphasize again the fact that the product of large mining operations on low-grade deposits has for many years formed

a considerable part of the mineral output of the Territory. This kind of mining began with the exploitation of the Treadwell auriferous lode in 1887. During the last two decades low-grade deposits of copper, placer gold, etc., have been profitably worked in other parts of the seaboard region of Alaska. The minerals recovered from these large operations have a total value of about $105,000,000, of which nearly $76,000,000 is to be credited to the mines of the Juneau district. This total includes the value of the mineral output from (1) auriferous lodes that yield ores whose gold and silver content is valued at less than $2.50 a ton, (2) copper deposits containing an average of not more than 3 per cent of copper, (3) placers having a gold content of less than 75 cents to the cubic yard, and (4) marble and gypsum of southeastern Alaska. All the low-grade deposits thus far developed are at or near tidewater and therefore have not had to bear the high cost of land transportation, which can be borne only by bonanza deposits. Many mineral deposits of low grade are known in Alaska, and the prospect of finding others is good. The exploitation of large mineral deposits of this kind yields only a small profit per ton, but under normal industrial conditions this disadvantage is offset by the large tonnage handled. Under the present high operating costs and the relatively low market value of mineral products the profits on certain operations are entirely swept away, so that during the last two years there has been no incentive to this form of mining in Alaska, and no large mining ventures have been undertaken.

As about 96 per cent of the mineral output of Alaska, measured in value, has been taken from her gold and copper mines, the world-wide depression in the mining of these two metals, which continued through 1920, has been a staggering blow to the prosperity of the Territory. About 60 per cent of the population of Alaska has heretofore been directly or indirectly supported by gold mining, and with the relative decrease in the value of gold the population has decreased, for the miner or prospector has been forced to leave the Territory. This decrease, however, must not be regarded as an indication of the early exhaustion of the gold resources, for Alaska contains enormous potential reserves of gold and other minerals.[1] The depression of the mining industry is only temporary; a change for the better will come when general economic conditions become more nearly normal and water and land transportation are cheaper and better. A lowering of freight rates, the completion of the Government railroad, and the building of a large mileage of wagon roads are needed to quicken the now stagnant mining industry. Such changes will, however, take time, so that an immediate general improvement can not be expected.

[1] Brooks, A. H., The future of Alaska mining: U. S. Geol. Survey Bull. 714, pp. 5-57, 1921.

The prospects of successfully exploiting the mineral fuels have been improved somewhat by the coal-land leasing act of 1913, but unfortunately this act became effective during the period when industrial conditions were made unstable by the World War and by the readjustments that followed peace. In 1920 further help was given by the passage of an oil-land leasing act, but this act has not been in force long enough to affect the Alaska mining industry.

The interdict which long existed on the use of the mineral fuels of Alaska greatly retarded all forms of mining in the Territory. It not only enhanced the cost of mining by prohibiting the use of local fuels, but it made the industry lose the benefit of the improvement in industrial conditions that would certainly have followed the development of coal and oil. In spite of these conditions gold and copper mining in Alaska has been very prosperous, principally because there has been no direct interference to prevent their normal development. Had metal mining been subject to restrictions similar to those imposed on the development of mineral fuels the Alaska mining industry would to-day be still in its infancy.

The number of men engaged each year in productive mining gives a rough measure of the prosperity of the industry, but unfortunately complete statistics of the number of men employed in mining are not available. A careful study of all the facts at hand appears to justify the following estimates,[a] which include only the men employed at mines that made some mineral output during the year.

Estimates of number of men employed at productive mines of Alaska, 1911–1920.

Year.	Placer mines.		Lode mines and reduction plants.	All other mining and quarrying.	Total men engaged in mining, not including winter placer mines.
	Summer.	Winter (omitted from total).			
1911	4,900	670	2,360	150	7,410
1912	4,500	900	2,560	150	7,210
1913	4,500	800	3,450	140	8,090
1914	4,400	800	3,500	140	8,040
1915	4,400	700	3,850	160	8,410
1916	4,050	880	4,570	340	8,960
1917	3,550	950	3,220	270	7,040
1918	3,000	610	2,000	400	5,400
1919	2,180	320	1,900	310	4,390
1920	1,990	340	1,880	360	4,230

[a] The reports of the Geological Survey contain estimates of the number of men engaged in placer mining for each year since 1910, and miscellaneous notes on the number of men employed in other branches of the mining industry. The following publications also give much valuable information about the number of men employed, especially in lode mining:

Smith, S. S., Report of the mine inspector for the Territory of Alaska to the Secretary of the Interior for the fiscal year ended June 30, 1912, Washington, 1913. Same for the fiscal year ended June 30, 1913, Washington, 1914. Same for the fiscal year ended June 30, 1914, Washington, 1914.

Maloney, William, Report of the Territorial mine inspector to the governor of Alaska, for the year 1915 [Juneau, Alaska, 1916]. Same for the year 1916 [Juneau, Alaska, 1917]. Same for the year 1917 [Juneau, Alaska, 1918].

Stewart, B. D., Annual report of the Territorial mine inspector to the governor of Alaska, 1920, Juneau, Alaska, 1921.

In considering the above table it should be remembered that the summer placer mines are operated for an average period of less than 100 days in a year. A comparison of the first two columns shows that only a small percentage of the men engaged in summer placer mining can find similar employment in the winter. As the winter placer mining is all done through shafts and drifts it is closely related to lode mining. Some of the deep placer mines are operated for nearly the entire year and hence are included in the total summer mines also. The lode mines include copper and gold and a few other metal mines. The fourth column shows the number of men engaged in all other forms of mining and quarrying, including the exploitation of coal, petroleum, marble, tin, gypsum, etc.

Mineral output of Alaska, 1919 and 1920.

	1919		1920		Decrease or increase in 1920.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold.....fine ounces..	455,984	$9,426,032	404,683	$8,365,560	− 51,301	−$1,060,472
Copper......pounds..	47,220,771	8,783,063	70,435,363	12,960,106	+23,214,592	+ 4,177,043
Silver....fine ounces..	629,708	705,273	953,546	1,039,364	+ 323,838	+ 334,091
Coal.......short tons..	60,674	343,547	61,111	355,668	+ 437	+ 12,121
Tin, metallic....do....	56	73,400	16	16,112	− 40	− 57,288
Lead............do....	687	72,822	875	140,000	+ 188	+ 67,178
Platinum minerals, fine ounces.	569.52	73,663	1,478.97	160,117	+ 909.45	+ 86,454
Miscellaneous nonmetallic products, including petroleum, marble, and gypsum.	....	143,113	....	266,830	....	+ 123,717
	....	19,620,913	....	23,303,757	....	+ 3,682,844

Value of total mineral production of Alaska, 1880–1920.

By years.				By substances.	
1880–1890	$4,686,714	1907	$20,850,235	Gold	$320,080,553
1891	916,920	1908	20,145,632	Copper	127,486,202
1892	1,098,400	1909	21,146,963	Silver	7,342,892
1893	1,051,610	1910	16,887,244	Coal	1,796,128
1894	1,312,567	1911	20,691,241	Tin	934,264
1895	2,388,042	1912	22,536,849	Lead	662,258
1896	2,981,877	1913	19,476,356	Antimony	237,500
1897	2,540,401	1914	19,065,666	Marble, gypsum, petroleum, platinum, etc	2,984,992
1898	2,587,815	1915	32,854,229		461,474,789
1899	5,706,226	1916	48,632,212		
1900	8,241,734	1917	40,710,205		
1901	7,010,838	1918	28,253,961		
1902	8,403,153	1919	19,620,913		
1903	8,944,134	1920	23,303,757		
1904	9,569,715		461,474,789		
1905	16,480,762				
1906	23,378,428				

NEW DEVELOPMENTS.

One of the most encouraging features of the year's mining was the systematic development of a large auriferous lode in the Nixon Fork (McKinley) district, in the upper Kuskokwim Valley. This ore body gives promise of being valuable, and if the promise is fulfilled the

beginning of a lode-mining industry in this remote region will be assured. Auriferous mineralization appears to have taken place rather widely in the Kuskokwim basin, a region which has been relatively little prospected. The gold of this region is associated with granitic rocks, which are intruded into limestone and other little-altered sedimentary rocks. In general the strong mineralization appears to be more localized than that in the schist areas of the upper Yukon, and the conditions are therefore favorable to the occurrence of commercial ore bodies.

The discovery of this lode and the continued success of the Candle Creek dredge near McGrath have attracted attention to the Kuskokwim basin, and more prospecting has consequently been done in this region than in any other part of inland Alaska. Especially noteworthy has been the considerable search and the numerous tests for dredging ground here and in the region immediately adjacent during the last two years.

Though lode mining in southeastern Alaska is still chiefly confined to the low-grade ores of Juneau, whose development is seriously handicapped by the existing conditions, yet there was in 1920 a marked increase in prospecting for auriferous lodes in this field, notably in the Sitka district. Promising discoveries of auriferous quartz were made on Chichagof Island. Important also were the activities in the Willow Creek district, in the Susitna basin, tributary to the Government railroad, which were directed to the consolidation of some auriferous lode properties and their development on a large scale.

One of the most important events of the year was the beginning of systematic underground exploration of the Matanuska coal field under the auspices of the Navy Department. This exploration has for its purpose the development of high-grade coal for the use of the Navy, but incidentally it should afford a thorough test of the commercial possibilities of the field.

The enactment of the oil-land leasing law in February, 1920, together with the world-wide search for petroleum, have again attracted public attention to the oil in Alaska. There has not yet been sufficient time to drill under the new régime, but more than 700,000 acres of land has been staked on the assumption that it is oil bearing. The evidence in hand indicates that though a part of this land is well worth drilling many of the places staked now, as during all oil booms, will be found worthless. There is, however, a very good prospect of developing producing wells in Alaska.

GOLD AND SILVER.

TOTAL PRODUCTION.

The total production of gold and silver since the beginning of mining in 1880 is given in the following table. For the earlier years the figures, especially those for silver, are probably far from correct, but they are based on the best information now available.

Gold and silver produced in Alaska, 1880–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Commercial value.
1880	967	$20,000		
1881	1,935	40,000		
1882	7,256	150,000		
1883	14,561	301,000		
1884	9,724	201,000	10,320	$11,146
1885	14,512	300,000		
1886	21,575	446,000		
1887	32,653	675,000		
1888	41,119	850,000	2,320	2,181
1889	43,538	900,000	8,000	7,490
1890	36,862	762,000	7,500	6,071
1891	43,538	900,000	8,000	7,920
1892	52,245	1,080,000	8,000	7,000
1893	50,213	1,038,000	8,400	6,570
1894	62,017	1,282,000	22,261	14,257
1895	112,642	2,328,500	67,200	44,222
1896	138,401	2,861,000	145,300	99,087
1897	118,011	2,439,500	116,400	70,741
1898	121,760	2,517,000	92,400	54,575
1899	270,997	5,602,000	140,100	84,276
1900	395,030	8,166,000	73,300	45,494
1901	335,369	6,932,700	47,900	28,598
1902	400,709	8,283,400	92,000	48,590
1903	420,069	8,683,600	143,600	77,843
1904	443,115	9,160,000	198,700	114,934
1905	756,101	15,630,000	132,174	80,165
1906	1,066,030	22,036,794	203,500	136,345
1907	936,043	19,349,743	149,784	98,857
1908	933,290	19,292,818	135,672	71,906
1909	987,417	20,411,716	147,950	76,934
1910	780,131	16,126,749	157,850	85,239
1911	815,276	16,853,256	460,231	243,923
1912	829,436	17,145,951	515,186	316,839
1913	755,947	15,626,813	362,563	218,988
1914	762,596	15,764,259	394,805	218,327
1915	807,966	16,702,144	1,071,782	543,393
1916	834,068	17,241,713	1,379,171	907,495
1917	709,049	14,657,353	1,239,150	1,021,060
1918	458,641	9,480,952	847,789	847,789
1919	455,984	9,426,032	629,708	705,273
1920	404,683	8,365,560	953,546	1,039,364
	15,481,476	320,030,553	9,972,562	7,342,892

The subjoined table gives an estimate, based on the best available data, of the gold and silver produced in Alaska from different sources since mining began in 1880. About $65,900,000 worth of gold, or about one-fifth of the total estimated output, was produced before 1905, and there is but scant information about its source. For the period since that time fairly complete statistics are available, and the figures presented in the following table are probably sufficiently accurate to be valuable. The figures given for the silver recovered

from placer gold and from siliceous ores are probably less accurate than those for the gold. Copper mining did not begin in Alaska until 1901, and the figures for gold and silver derived from this industry therefore represent approximately the actual output.

Gold and silver produced in Alaska from different sources, 1880–1920.

	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Siliceous ores [a]	4,662,942	$96,391,594	1,674,872	$1,321,588
Copper ores	84,799	1,752,967	6,497,919	4,956,834
Placers	10,733,735	221,885,992	1,799,771	1,064,470
	15,481,476	320,030,553	9,972,562	7,342,892

[a] Including small amounts of galena ore.

The above table shows that 30 per cent of all the gold produced in Alaska since 1880 has been obtained from siliceous ores. During the last decade there has been a gradual increase in the percentage of the annual gold output from the auriferous lodes. In 1911 the proportion was 25 per cent; in 1915, 37 per cent; in 1919, 46.6 per cent, and in 1920, 53 per cent.

Gold and silver produced in Alaska, 1920, by sources.

	Ore.	Gold.		Silver.	
		Quantity. (fine ounces).	Value.	Quantity. (fine ounces).	Value.
Siliceous ores.....tons..	3,413,021	216,414	$4,473,687	246,292	$268,458
Copper ores.....do....	765,025	913	18,873	682,033	743,416
Placers.....cubic yards of gravel..	3,439,974	187,356	3,873,000	25,221	27,490
	....	404,683	8,365,560	953,546	1,039,364

LODE MINING.

Seventeen gold-lode mines and five prospects were operated in 1920 and produced gold worth $4,473,687. Twenty-three gold-lode mines and two prospects were operated in 1919 and produced gold worth $4,392,237. This increase came entirely from the gold mines of southeastern Alaska, as the output from all the other districts declined. It is not likely that the output from the low-grade mines of the Juneau district will be maintained, and unless there is an increase elsewhere the gold-lode output of Alaska probably will be less in 1921 than it was in 1920. There is most hope for an increase from the Willow Creek district, where a large consolidation of mines was made in 1920, and operations on a larger scale than heretofore are to be expected.

Gold and silver produced from gold-lode mines in Alaska, 1920, by districts.

District.	Mines operated.	Ore mined (short tons).	Gold.		Silver.		Average value per ton of ore in gold and silver.
			Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.	
Southeastern Alaska	8	3,409,197	210,536	$4,352,165	114,621	$124,986	$1.31
Willow Creek	3	2,850	3,067	63,400	146	158	22.30
Fairbanks district	[a] 2	504	967	20,000	164	178	40.03
Other districts	[b] 4	1,165	1,844	38,122	131,361	143,186	155.63
	17	3,413,716	216,414	4,473,687	246,292	268,458	1.39

[a] In addition a small tonnage of ore was produced from 5 prospects.
[b] Includes 1 small mine in Kantishna district, 1 in McKinley district, and 2 in Kenai Peninsula.

Of the eight mines in southeastern Alaska only four made a large output, that of the other four being only incidental to development work. The reduction in the number of producing mines in the Willow Creek district, from five in 1919 to three in 1920, was due to a combination of three properties which are to be worked as a unit, and there was an actual output from only one of these properties. In 1920, as in 1919, little work was done on the gold lodes in the Fairbanks district, for the owners of the mines in this district are awaiting cheaper operating costs before continuing developments. The great increase in the silver ouput of the lode mines, as indicated by the above table, is to be credited to the small mine in the Kantishna district, whose principal ore is galena carrying a high percentage of silver. For many years the average value per ton of ore of the gold and silver recovered from Alaska siliceous ores was about $2.80. This high value was due to the preponderance of the metals in the ore produced from the mines of the Treadwell group. When, in 1915 and 1916, the output of the lower-grade ores of the Perseverance and Alaska Juneau mines began to be larger, the value of the average recovery fell below $2 per ton, and the value was still further reduced when two of the Treadwell mines closed in 1917. The average value per ton of ore of the gold and silver mined in Alaska in 1919 was $1.38, and the average value in 1920 was $1.39.

One of the most encouraging features of lode mining in southeastern Alaska is the work being done on Chichagof and Admiralty islands, where promising auriferous lodes are being developed. The advances in lode mining made in the Willow Creek district have already been referred to. The Cliff and possibly the Granite lode mine of Prince William Sound may again be productive in 1921.

PLACER MINING.

During 41 years of mining Alaska has produced gold to the value of $320,000,000, and $217,885,000 of this amount is to be credited to her placer mines. For reasons already discussed less placer

mining was done in 1920 than in 1919, and the profits on actual operations were also less. Though the general fall of prices will eventually benefit the Alaska placer mines, yet it is not likely to prevent a further decline of the industry in 1921. Except the installation of some dredges no new large placer-mining projects are definitely under way. Investigations of large bodies of gold-bearing gravel are, however, being made in several districts, and if these result in mining operations a revival of the industry is assured. Meanwhile any lowering of operating costs by cheaper freight rates and cheaper supplies will quicken the mining activities of the smaller operators. It can not be too strongly emphasized that the enormous alluvial gold reserves of Alaska [a] give every assurance of the eventual revival of placer mining. In the following table a comparison is made between the condition of the placer-mining industry in 1920 and its condition in 1919:

Alaska placer mining, 1919 and 1920.

Region.	Number of mines.				Number of miners.				Value of gold produced.		Decrease or increase, 1920.
	Summer.		Winter.		Summer.		Winter.				
	1919	1920	1919	1920	1919	1920	1919	1920	1919	1920	
Southeastern and southwestern Alaska	14	18	......	......	39	18	......	......	$30,000	$10,000	−$20,000
Copper River region	18	19	......	......	115	94	......	......	185,000	200,000	+ 15,000
Cook Inlet and Susitna region	21	27	......	......	81	70	......	......	110,000	55,000	− 55,000
Yukon basin	274	273	76	69	1,246	1,130	255	271	2,910,000	1,995,000	−915,000
Kuskokwim region	20	32	2	......	101	125	3	......	350,000	305,000	− 45,000
Seward Peninsula	103	112	10	8	555	540	60	61	1,360,000	1,300,000	− 60,000
Kobuk region	16	7	......	5	40	10	......	9	25,000	8,000	− 17,000
	466	488	88	82	2,177	1,987	318	341	4,970,000	3,873,000	1,097,000

The above table shows that there was a decrease of about 22 per cent in the value of the output of placer gold in 1920 as compared with 1919, and also that the chief loss was in the Yukon camps, where the decrease was 31 per cent. It also indicates that, measured by production, the districts on Seward Peninsula were the most prosperous. A still greater decrease in the output of placer gold from Alaska is to be expected in 1921. The record of 488 placer mines operated in the summer of 1920 and 82 in the previous winter somewhat exaggerates the activity of the industry. These totals, like those given in all previous reports, include every placer-mine operation of the year, no matter how small, and among them are many whose output for the year amounted to only a few hundred dollars. About 150 mines were operated in the summer of 1920 and 20 mines

[a] Brooks, A. H., The future of Alaska mining: U. S. Geol. Survey Bull. 714, pp. 7-11, 1921.

in the previous winter that produced less than $1,200 worth of gold per mine. The total value of the gold produced by these mines was $95,000, and they employed about 230 men. Sufficiently complete returns have been received from 100 of these mines to permit the analysis of their operations presented in the following table:

Operations of small gold-placer mines in Alaska in 1920.

[Includes only mines whose gold output for the year was $1,200 or less.]

Region.	Number of mines considered.	Number of men employed.	Average number of days' work per man.	Average number of cubic yards of gravel mined per man per day.	Value of gold recovered—		
					Per cubic yard.	Per man per day.	Per man for the year.
Southeastern Alaska, Copper River, and Susitna River districts	15	23	45	7.4	$1.03	$7.63	$343
Yukon and Kuskokwim districts	67	86	76	4.8	1.10	5.28	401
Seward Peninsula and Kobuk districts	18	27	50	5.8	1.37	7.92	396
	100	136	67	5.3	1.13	4.94	398

About 70 per cent of these operations consisted of development work on placer deposits, which are expected to yield satisfactory returns at some future time, when the economic conditions are more favorable or better equipment can be obtained. Some placer gold was recovered during this work. The other 30 per cent of these operations consisted of mining small and rich pockets of gold-bearing gravel exploited by "snipers" or "pocket hunters" solely to obtain an immediate livelihood. Many millions of dollars' worth of gold has been won by this kind of mining. The richest field of the sniper was the beach placers of Nome in 1899 and 1900. The bars of Fortymile River have been yielding returns to the sniper since their discovery in 1886. In recent years, however, no new fields for the sniper have been found, and, as the above table shows, his returns have been very meager. Unless new bonanzas are found mining of this kind must therefore inevitably cease, except in so far as it may be done by men who obtain their principal support from some other work.

As shown above, the average return to the small miner in 1920 was only $398. A careful estimate, based on retail prices at Fairbanks, shows that the cost of a year's provisions for one man in 1920 was $420. Supplies are considerably cheaper in the districts nearer the coast but are much higher in the isolated camps than at Fairbanks. A year's provisions for a man, including only necessities, will probably cost from $300 to $500, and will average above $398. The returns in gold from these small mines are therefore not paying the cost of the provisions consumed.

This loss is in part offset by the fact that the miner works on the average only 67 days a year; living in a cabin built by himself he pays no rent, and his fuel, which is wood, he obtains for the labor of cutting it. In most places his provisions are helped out by fish and game, and he may be able to raise his potatoes and other vegetables. Furthermore, many small miners get a much larger return from fur hunting in winter than from mining in summer. In estimating the number of days' work it should be noted that the small miner must spend a certain number of days each year in transporting his supplies from the nearest trading post, in cutting his fuel, in building cabins, in making sluice boxes, and in doing other work, none of which is included in the average 67 days of mining. Taking together the time devoted to mining and to the work just mentioned, the average small miner will probably not be employed more than half the year. If, therefore, he can find remunerative occupation, such as trapping or cutting wood during the rest of the year he may still make a fair income, and if he is developing a mineral deposit that will give good profits in the future he may be bettering himself economically.

The increased cost of supplies is a serious hardship to the small operator. It not only reduces the net returns on mining his own claim, but by reducing the larger operations it prevents his finding employment with the mining companies. It is probably safe to estimate that the cost of clothing, traveling, tools, etc., added to that of provisions, will bring the average annual expense of the Alaska miner up to $700 or $800. It will therefore be necessary for him to earn an additional sum of money at least equal to the return from his mine, taken as the average return of 1920. The returns for 1920 (see table above) show that he is mining placers whose value is only $1.13 a cubic yard, and he is mining an average of 5.3 cubic yards a day, which gives him an average daily wage of $5.94. If he is to obtain his actual living expenses from mining alone he must confine his efforts to deposits which carry at least $2 worth of gold to the cubic yard, which will give him a daily wage of $10 and, with an average of 67 working days, an annual return of $670.

If the small mines as defined above and the gold dredges are excluded the summer placer mines operated in 1920 numbered 317, employing 1,832 men, and the winter placer mines numbered 62, employing 278 men. In these winter placers the gold-bearing gravel is thawed in winter and is sluiced after the summer thawing. The total value of the gold recovered by placer mining was $1,478,068. The gold and silver output of placer mines by regions is shown in the following table:

Gold and silver produced from placer mines in Alaska, 1920, by regions.

Region.	Gold.		Silver.		Gravel mined (cubic yards).	Recovery per cubic yard.
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.		
Southeastern and southwestern Alaska	483.75	$10,000	83.27	$91	2,750	$3.64
Copper River region	9,674.99	200,000	1,014.78	1,106	160,000	1.25
Cook Inlet and Susitna region	2,660.62	55,000	397.02	432	78,000	.70
Yukon basin	96,508.08	1,995,000	12,905.46	14,068	1,272,924	1.57
Kuskokwim region	14,754.36	305,000	3,962.98	4,320	131,900	2.31
Seward Peninsula	62,887.49	1,300,000	6,813.06	7,426	1,792,100	.73
Kobuk region	387.00	8,000	44.47	48	2,300	3.47
	187,356.29	3,873,000	25,221.04	27,490	3,439,974	1.13

The following table shows approximately the total bulk of gravel mined annually since 1907 and the value of the gold recovered per cubic yard. This table is based in part on returns made by operators of placer mines and in part on known facts or assumptions concerning the richness of the gravels in the several districts. Although the table is thus in part an estimate it is probably nearly correct.

Gravel sluiced in Alaskan placer mines and value of gold recovered, 1908–1920.

Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.	Year.	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.
1908	4,275,000	$3.74	1915	8,100,000	$1.29
1909	4,418,000	3.66	1916	7,100,000	1.57
1910	4,036,000	2.97	1917	7,000,000	1.40
1911	5,790,000	2.17	1918	4,931,000	1.20
1912	7,050,000	1.70	1919	4,548,000	1.10
1913	6,800,000	1.57	1920	3,439,974	1.13
1914	8,500,000	1.26			

The table shows that from 1908 to 1914 there was a decline in the average gold content of the gravels mined. This decline reflects the improved methods of placer mining that have been introduced, more especially the increase in the use of dredges, which is brought out in the following table:

Relation of recovery of placer gold per cubic yard to proportion produced by dredges.

	Percentage of placer gold produced by dredges.	Recovery per cubic yard.		
		Dredges.	Mines.	All placers.
1911	12	$0.60	$3.36	$2.17
1912	18	.65	2.68	1.70
1913	21	.54	3.11	1.57
1914	22	.53	2.07	1.26
1915	22	.51	2.33	1.29
1916	24	.69	2.64	1.57
1917	26	.68	2.21	1.40
1918	24	.57	1.84	1.20
1919	27	.77	1.31	1.10
1920	29	.69	1.53	1.13

The 22 dredges operated in 1920 employed crews numbering 145 men. Two of these dredges were in the Fairbanks district, 2 in the Iditarod, 1 in the Mount McKinley (McGrath) district, and 17 in Seward Peninsula. The average gold recovery of the 5 Yukon and Kuskokwim dredges was 94 cents per cubic yard, and that of the Seward Peninsula dredges was 48 cents per cubic yard. The inland dredges were operated for an average of 170 days, and the longest season was that in the Iditarod, which ran for 196 days. The Seward Peninsula dredges were operated for an average of 66 days, and the longest season for any one dredge was 96 days.

Gold produced by dredge mining in Alaska, 1903–1920.

Year.	Number of dredges operated.	Value of gold output.	Gravel handled (cubic yards).	Value of gold recovered per cubic yard.
1903	2	$20,000		
1904	3	25,000		
1905	3	40,000		
1906	3	120,000		
1907	4	250,000		
1908	4	171,000		
1909	14	425,000		
1910	18	800,000		
1911	27	1,500,000	2,500,000	$0.60
1912	38	2,200,000	3,400,000	.65
1913	35	2,200,000	4,100,000	.54
1914	42	2,350,000	4,450,000	.53
1915	35	2,330,000	4,600,000	.51
1916	34	2,679,000	3,900,000	.69
1917	36	2,500,000	3,700,000	.68
1918	28	1,425,000	2,490,000	.57
1919	28	1,360,000	1,760,000	.77
1920	22	1,129,932	1,633,861	.69
		21,524,932		

COPPER.

The copper output of Alaska was 70,435,363 pounds, valued at $12,960,106, in 1920, and 47,220,771 pounds, valued at $8,783,063, in 1919. This increase is to be credited almost entirely to 3 mines of the Kennecott group, in the Chitina basin, and the Beatson mine, on Prince William Sound. Eight copper mines were operated productively in 1920 as compared with 11 in 1919. Of the productive mines, 2 on Prince William Sound were under development and recovered only small amounts of ore incidentally. The total copper output shown in the following table includes, in addition to that of the copper mines, some copper won from ores mined chiefly for other metal.

Output of Alaska copper mines in 1920, by districts.

District.	Mines operated.	Ore (tons).	Copper.		Gold.		Silver.	
			Quantity (pounds).	Value.	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Ketchikan [a]	2	16,088	670,155	$123,308	912.72	$18,868	5,313	$5,791
Chitina [b]	2	[c] 295,473	55,997,660	10,303,569			557,553	607,733
Prince William Sound	4	454,534	13,767,548	2,533,229			119,167	129,892
	8	766,095	70,435,363	12,960,106	912.72	18,868	682,033	743,416

[a] Includes some copper shipments from other parts of Alaska.
[b] Kennecott Copper Corporation Annual Report for 1920.
[c] Includes a small amount of placer copper.

The average copper content of the ore mined in 1920 was 4.6 per cent. The ores yielded an average of $0.025 in gold and $0.97 in silver to the ton. The average yield for 1919 was 4.8 per cent copper, $0.129 in gold, and $1.11 in silver. The large reduction in the average gold content of the ores mined in 1920 as compared with those mined in previous years is due to the closing of the Ellamar mine, whose ores carried much gold.

Of the total copper ore mined in Alaska in 1920, 96 per cent, or 732,549 tons, was treated by oil flotation, yielding 80,342 tons of concentrates, which averaged 32 per cent of copper. Most of the copper ore mined in 1920 was shipped to the Tacoma smelter, but a part of that mined in southeastern Alaska was treated at the Anyox smelter, in British Columbia.

Copper produced in Alaska, 1880–1920.

Year.	Ore mined (tons).	Copper produced.	
		Quantity (pounds).	Value.
1880		3,933	$826
1901		250,000	40,000
1902	[a] 40,000	360,000	41,400
1903		1,200,000	156,000
1904		2,043,586	275,676
1905	52,199	4,805,236	749,617
1906	105,729	5,871,811	1,133,260
1907	98,927	6,308,786	1,261,757
1908	51,509	4,585,362	605,267
1909	34,669	4,124,705	536,211
1910	39,365	4,241,689	538,695
1911	68,975	27,267,878	3,408,485
1912	93,452	29,230,491	4,823,031
1913	135,756	21,659,958	3,357,293
1914	158,605	21,450,628	2,852,934
1915	369,600	86,509,312	15,139,129
1916	617,264	119,854,839	29,484,291
1917	659,957	88,793,400	24,240,598
1918	722,047	69,224,951	17,098,563
1919	492,644	47,220,771	8,783,063
1920	766,095	70,435,363	12,960,106
	4,501,793	615,442,699	127,486,202

[a] Estimated.

In 1920, as in previous years, the Rush & Brown copper mine was the largest copper producer in southeastern Alaska. Copper was produced also at the Salt Chuck mine, better known for its production of palladium. Relatively little prospecting and no considerable development work was done on the copper deposits of southeastern Alaska. The three large mines, the Bonanza, Jumbo, and Mother Lode, were the only producing mines of the Chitina district in 1920, and no considerable developments were made at other mines. Some alluvial copper was produced incidentally to gold-placer mining in the Nizina district. On Prince William Sound the Beaton mine was the only property operated systematically throughout the year. The most notable advances were made at the Girdwood mine, where systematic underground and surface work was continued during much of the year. Small developments were continued at the Schlosser and McIntosh mines through a part of the year.

The above review shows that the Alaska copper-mining industry is in a rather discouraging situation in spite of the relatively large output of the metal in 1920. Except possibly in Prince William Sound, no large amount of work was done during the year in opening new ore bodies. The falling copper market and certain local conditions have discouraged the launching of any new enterprises. Not only will the copper output of 1921 be far less than that of 1920, but probably several years will pass before any new large copper-mining ventures will be under way.

LEAD.

The lead produced in Alaska in 1920 amounted to 875 tons, valued at $140,000, as compared with 687 tons, valued at $72,822, in 1919. In 1920, as in other years, most of the lead output was a by-product derived from the gold ores of the Juneau district. The increase in 1920 over 1919 was derived largely from galena ore mined in the Kantishna district.

The recent development of rich silver-lead ores in the Mayo district[4] of the Yukon Territory, about 100 miles east of Dawson, has started a search for similar deposits on the Alaska side of the boundary, not because of the lead content of the ore but because of the recent high price of silver. Galena ores are rather widely distributed in Alaska, but no large deposits have been found. Though some work was done on a number of Alaska galena deposits in 1920, which will be referred to in the review by districts, to follow (pp. 43–54), only one mine, in the Kantishna district, shipped any ore.

[4] Cockfield, W. E., The Mayo area, Yukon: Canada Geol. Survey Summary Rept., 1918, pp. 1B–22B, Ottawa, 1919.

Lead produced in Alaska, 1892–1920.

Year.	Quantity (tons).	Value.	Year.	Quantity (tons).	Value.
1892	30	$2,400	1908	40	$3,360
1893	40	3,040	1909	69	5,934
1894	35	2,310	1910	75	6,600
1895	20	1,320	1911	51	4,590
1896	30	1,800	1912	45	4,050
1897	30	2,160	1913	6	528
1898	30	2,240	1914	28	1,344
1899	35	3,150	1915	437	41,118
1900	40	3,440	1916	820	113,160
1901	40	3,440	1917	852	146,584
1902	30	2,460	1918	564	80,088
1903	30	2,520	1919	687	72,822
1904	30	2,580	1920	875	140,000
1905	30	2,620			
1906	30	3,420		5,059	662,258
1907	30	3,180			

TIN.

The tin mines of Alaska produced 26 tons of ore, containing 32,000 pounds of tin, valued at $16,112, in 1920, as compared with 86 tons of ore, containing 112,000 pounds of tin, valued at $73,400, in 1919. This decrease of output was due largely to the fact that in 1920 only one tin dredge instead of two, as in 1919, was operated in the York district of Seward Peninsula, which is the only important tin-producing area in Alaska. None of the tin mined in 1920 was marketed before the end of the year. In the York district the American Tin Mining Co. operated its dredge on Buck Creek from July to October. Some open-cut mining was done with pick and shovel on Goodwin Creek. During the winter of 1919-20 about 20 men were employed in developing the Lost River tin mine, on Cassiterite Creek. A 250-foot incline was sunk on the tin-bearing dikes from a station on the lower tunnel. Work was suspended in May, 1920.

It is reported that the tin placers of Grouse Creek have been worked out and that at the present rate of mining the placers of Buck Creek may be exhausted in about five years. Meanwhile sufficient prospecting has been done on other creeks to give reasonable assurance that the tin production will be maintained. Tin-bearing gravels have been prospected on Potato Creek and on Goodwin Creek and its tributary, Percy Gulch, flowing northward to the Arctic Ocean, as well as on Cape Creek, flowing southward to Bering Sea. Tin has been found on other creeks in the district, but on these creeks the prospecting is said to have developed some good dredging ground, and plans to install dredges on them are under consideration.

Though the only mines exploited solely for tin were the two in the York district, 7 of the Yukon gold-placer mines reported the recovery of some tin. Of these 6 were in the Hot Springs district and 1 in the Ruby district.

Tin produced in Alaska, 1902–1920.

Year.	Quantity (tons).		Value.	Year.	Quantity (tons).		Value.
	Ore.	Metal.			Ore.	Metal.	
1902	25	15	$8,000	1913	98	50	$44,103
1903	41	25	14,000	1914	157.5	104	66,560
1904	23	14	8,000	1915	167	102	78,846
1905	10	6	4,000	1916	232	139	121,000
1906	57	34	38,640	1917	171	100	123,300
1907	37.5	22	16,752	1918	104.5	68	118,000
1908	42.5	25	15,180	1919	86	56	73,400
1909	19	11	7,638	1920	26	16	16,112
1910	16.5	10	8,335				
1911	92.5	61	52,798		1,600.0	988	934,264
1912	194	130	119,600				

PLATINUM METALS.

The output of platinum, palladium, and other metals of the platinum group in Alaska in 1920 is estimated at 1,476.97 ounces, valued at $160,117, as compared with 569.25 ounces, valued at $73,663, in 1919. In 1920, as in previous years, the larger part of the output was from the copper-palladium ore of the Salt Chuck mine, in the Ketchikan district. An output of platinum minerals was reported by 7 gold placer mines in 1920. Four of these were in the Koyuk district and one in the Fairhaven district of Seward Peninsula. Two placer mines in the Chistochina district of the Copper River basin produced platinum in 1920. The largest output of placer platinum was made on Dime Creek, in the Koyuk district, and on Slate Creek, in the Chistochina district. The bedrock source of the alluvial platinum has not yet been definitely determined. The total production of platinum metals in Alaska since they were first saved, in 1916, is given in the following table:

Platinum metals produced in Alaska, 1916–1920.

Year.	Quantity.		Value.
	Crude ounces.	Fine ounces.	
1916	12.0	8.33	$700
1917	81.2	53.40	5,500
1918	301.0	284.00	36,600
1919	579.3	569.52	73,663
1920	1,493.4	1,478.97	160,117
	2,466.9	2,394.22	276,580

QUICKSILVER.

Productive mining was continued in a small way at the Parks cinnabar mine, the only one in Alaska that has yet made an output. This mine is on the north bank of Kuskokwim River about 16 miles above Georgetown.

In 1919 a cinnabar-bearing lode was discovered in the headwater region of Iditarod River, a tributary of the Yukon. This deposit is said to be on Montana Creek, formerly called Moose Creek, 35 miles south of the town of Iditarod. Though it is on the Yukon side of the watershed, the place appears to be only about 10 miles in a direct line from the Kuskokwim. A trail about 15 miles long has been built from the Kuskokwim at the mouth of Crooked River to the deposit. Claims are under development by the Fidelity-Kuskokwim Quicksilver Co., which is said to have shipped about 60 tons of supplies, including retorts, during the summer of 1920. The underground development consists of a 50-foot shaft, said to reveal an ore body of considerable size. The deposit has not been examined by any member of the Geological Survey, but it is probably of the same general type as that found in the Iditarod district,[5] to the north, though it is reported to be much larger.

This newly discovered lode and the cinnabar deposits previously found are distributed over a considerable area, and cinnabar is not uncommon in the gold placers of this general region. This rather wide distribution of quicksilver ore augurs well for future discoveries, especially as but little prospecting has been done for cinnabar. Though most of the cinnabar-bearing lodes found thus far are too small to be of value yet there is good hope of finding commercially valuable bodies such as that on Montana Creek is reported to be.

MISCELLANEOUS METALS.

Antimony ore (stibnite) was mined at several places in Alaska during the World War, when the price of the metal was high. A total of 2,492 tons of stibnite ore, valued at $237,500, was mined in Alaska during 1916, 1917, and 1918. No antimony was mined in the Territory in 1920. The only developments reported were on the Norvill property, in Chicken Creek valley, in the Fortymile district. No tungsten has been mined in Alaska since 1918. It is reported that a deposit of chromite has been developed on the Whitney & Lass property, at Red Mountain, near the southern end of Kenai Peninsula, and that in the course of the work some ore was produced

The development of the molybdenite deposits near Shakan, on Prince of Wales Island, which has been going on for several years, was suspended in 1920. Oscar Yehring, of Juneau, discovered a molybdenite deposit near Glacier Bay in 1920. The deposit is near Wood Glacier, about 1½ miles from the beach and 200 feet above tidewater.

COAL.

The output of coal in Alaska in 1920 was 61,111 tons, valued at $355,668; the output in 1919 was 60,674 tons, valued at $343,547. Of the output in 1920, 35,044 tons was taken from the two Government

[5] Brooks, A. H., The antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 47-49, 1916.

mines in the Matanuska field. Besides these two mines there were only three others whose output for the year exceeded 1,000 tons—two in the Nenana field and one in the Kachemak Bay field. Lignitic coal for near-by use was produced at five other mines. The largest output from the small mines was made at the Kugruk mine, in the Fairhaven district, which supplied coal for some placer operations in its vicinity. The Alaska school service mined about 200 tons of coal for its use on Wainwright Inlet, north of Cape Lisburne. Ten mines, large and small, were operated during the year, employing 207 men for an average of 240 days.

Work at the Eska mine, in the Matanuska field, was continued on about the same scale as in previous years, to obtain coal for the Government railroad and for some of the near-by communities. The mine was operated 239 days, employing an average of 43 men underground and 50 men on the surface, which gave a total of 8,835 man-shifts underground and 15,609 man-shifts on the surface. There were 195 days lost owing to sickness, and the mine was closed 73 days on account of a strike. A total of 3,633 feet of gangways, etc., were driven in 1920, making 5,337 feet in all.[6] The resident engineer, S. S. Smith, reports that the cost of mining coal was about $6 a ton in 1920, compared with $5 in 1919 and $4.66 in 1918, and that the increase in cost was due to an increase of 32 per cent in the wages of miners,[7] the reduced output on account of the strike, a longer haul underground, and the greater cost of timber. The underground work consisted chiefly of mining coal beds, and but little advance work was done. The developed coal reserves are reported to be about 70,000 tons, which at the present rate of mining is about two years' supply. A washery having a capacity of 1,000 tons is being built and will be completed in 1921. It will be used for the Eska coal and for any other coal mined by the Government along the railroad.

In the summer of 1920 the Navy Department began systematic prospecting in the Matanuska field to find coal for use by the Navy. This work is directed by the Alaskan Naval Coal Commission, of which Commander O. C. Dowling is chairman. Sumner S. Smith, resident engineer, has the immediate technical direction of all the field work and has associated with him as geologists Prof. T. E. Savage, of the University of Illinois, and Lieut. W. P. T. Hill, of the Marine Corps. Prospecting and underground exploration have been actively pushed in the Chickaloon and Coal Creek areas, and some examinations have been made in other parts of the field. The results are reported to be encouraging, notably in the Coal Creek area, but details are not yet available for publication. The only other mining done in the Mata-

[6] Information on mining developments in the Matanuska field is taken from "Report of the mining department, Alaskan Engineering Commission, for 1920," by Sumner S. Smith, resident engineer, to whom the writer is indebted for an advance copy.

[7] Wages in 1920, per day of 8 hours, for skilled labor underground were $8.60; for unskilled labor, $7.90.

nuska field was on the leasehold of the Evans Jones Coal Co., near Eska. Underground work was started in October, 1920, to produce coal to be sledded to the railroad, about 1½ miles distant, during the winter. About five men were employed at the mine.

The Bering River Coal Co. continued the underground exploration and surface improvement of its leasehold in the western part of the Bering River field throughout the year. An average of 20 men were employed underground and 20 on the surface. No coal has been mined except that incidental to the development work, which supplied the wants of the mine. In all about 3,500 feet of crosscuts and gangways have been driven. In 1920 a plank automobile road 4 miles long was constructed, which gives connection with scow navigation at tidewater on Bering Lake. The company reports a total expenditure of nearly $400,000 up to the end of 1920.[8]

Some developments were continued by the Alaska Coal & Petroleum Co. on its patented coal claim in the eastern part of the field. The mine is connected with tidewater on Bering River by a small railroad.

The McNally mine, on Kachemak Bay, previously operated under a permit, is now operated under a leasehold, and larger developments are promised. It finds its principal market for its lignite product in the Cook Inlet region.

The Healy River Coal Corporation is operating a small lignite mine under leasehold on the west bank of Nenana River, opposite the mouth of Healy Fork. An adit[9] driven into the bank of Nenana River a few feet above water level reaches the coal about 200 feet in. An entry has been driven on the coal for about 300 feet. The coal is from 5 to 7 feet thick, and the floor and roof are of shale. The mine was worked throughout the year and employed about 12 men.

The Broad Pass Coal & Development Co. is operating under a permit a small lignite mine on Lignite Creek, a tributary of Nenana River from the east. It is worked only in winter, and the coal mined is carried across the Nenana on the ice. The coal bed is about 25 feet thick and lies nearly horizontal. In 1920 the mine was operated 80 days and employed 12 men underground and 9 on the surface, including those who sledded coal to the railroad.

The coal produced in the Nenana field was sold to the railroad and in the near-by settlements. Some coal was shipped to Fairbanks, where it was sold in carload lots at $7 a ton, but it has not yet there superseded wood as the general fuel.

The above review shows that the development of the high-grade Alaska coal has not yet gone beyond the prospecting stage. Indeed, the coal actually blocked out does not exceed a few hundred thousand

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[8] Kennecott Copper Corporation Ann. Rept. for 1920, p. 15, New York, 1921.

[9] Information received from B. W. Dyer, of the U. S. Bureau of Mines, and from George Parks, of the General Land Office.

tons, which, of course, is not an adequate base for a productive industry. This is the state of affairs after the coal fields have been open to leasehold for seven years, during which only one coal tract has been systematically explored by private capital. There is certainly a strong contrast between the present actual conditions and those foretold in the prophecies so freely made in the conservation propaganda a decade ago. Exaggerated statements of the value of the Alaska coals and of the profits sure to be realized by their development were then widely published and were generally accepted as true by those who had no technical knowledge of the subject and who failed to inform themselves by reading the official publications then extant. At the height of this propaganda every Alaska coal claimant was regarded by many as a prospective millionaire. After the actual facts were recognized the pendulum of popular opinion swung toward the other extreme, and some persons probably now believe that any interest in Alaska coal lands is a liability rather than an asset. The truth lies between these two extreme views.

The coal fields were opened for leasing about at the outbreak of the World War, and the industrial and financial revolution attendant on the war has no doubt delayed their development. Some men who attempted to develop leased tracts had neither the experience nor the capital to carry on the projects properly and were soon discouraged. The best hope for profitable exploitation of the Alaska high-grade coals is in operation on a large scale, calling for heavy investments. A great deal of preliminary underground exploration must be done to block out sufficient coal to justify the costly installation of large mining plants and, in the Bering River field, the construction of railroads. The conditions are in strong contrast to those affecting the eastern coals, which lie horizontal and are undisturbed, so that only a comparatively few openings are required to afford a reliable estimate of the quantity of coal available.

In view of the general importance of the fuel problem on our Pacific coast it will be well to summarize briefly the essential facts relating to the occurrence of the Bering River and Matanuska coals, even though they may be largely a repetition of what has long been published.[10] The underground work of the last few years has revealed

[10] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.

Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina valleys: U. S. Geol. Survey Bull. 592, pp. 273–300, 1914.

Martin, G. C., Geologic problems at the Matanuska coal mines: U. S. Geol. Survey Bull. 692, pp. 269–282, 1919.

Chapin, Theodore, Mining developments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 131–167, 1920; Mining developments in the Matanuska coal fields: U. S. Geol. Survey Bull. 714, pp. 197–199, 1921.

Brooks, A. H., The future of Alaska mining: U. S. Geol. Survey Bull. 714, pp. 43–51, 1921.

Martin, G. C., Geology and mineral resources of Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, 1908. (This publication contains a detailed description of the Bering River coal field.)

details concerning the occurrence of the coal that were not available when the earlier reports were published. Those reports were necessarily based solely on examinations of the outcrops and of the shallow pits of their day. In general, however, the conclusions then reached have been confirmed by the underground developments of recent years. For example, Martin [11] in his report on the Bering River field, published 13 years ago, says:

> The possible overturned folds and faults introduce problems the scope of which can perhaps be determined only by exploration of the seams in depth. It seems probable that there are areas within the field which can not be successfully mined. These must be determined by careful surface prospecting, followed by either boring or tunneling at critical points.

It has been known that the fuel value of the Alaska coals leaves little to be desired, though like many others of similar grade they will require washing. The friability of the coal favors cleaning by washing, as has been demonstrated by numerous tests. In general the quality of the coals appears to bear a more or less direct relation to the intensity of their deformation. For example, the coal of the Eska mine is both of a lower fuel value and much less disturbed than that of the Chickaloon mine. It also appears that the anthracite coals of the eastern part of the Bering River field are more intricately folded and faulted than the bituminous coals in the southwestern part of that field.

The most discouraging fact that has been brought out by the underground work is the lack of continuity of the coal beds. Most of those opened up thicken and thin very irregularly, and many pass into beds in which the carbonaceous material forms only a part and in some only a small part of the whole bed. These irregularities of occurrence are probably due largely to disturbances caused by folding and faulting, but they are also in part original features of deposition.

The evidence tends to show that the vegetable matter from which the coals were formed accumulated in small basins along valley bottoms and in river deltas rather than in extensive swampy lowlands. In coal beds formed from deposits that accumulated under the conditions stated there would naturally be recurring transition from clean coal well within the basins to dirty coal or even to clay sediments toward the rims of the basins. The mode of origin of the coal will therefore in part account for the lack of continuity of good coal beds. There is, however, no measure of the size of the basins in which the vegetable matter accumulated, and it probably varied greatly from place to place. These differences in original deposition are probably of less consequence to the miner than the folding and faulting of the beds, but a careful study of the conditions under which the coal was

[11] Op. cit. (Bull. 335), p. 93.

deposited will reveal facts which will aid in the identification and correlation of coal beds found in different mine openings. Furthermore, it may be possible that the most persistent coal beds as originally deposited may be found in the unprospected parts of both the Bering River and the Matanuska fields.

Though some of the variations in the thickness and composition of individual coal beds may be due to their mode of accumulation, there is no question that much of their extreme irregularity is certainly due to the profound disturbance of all the coal measures. This disturbance is general throughout both coal fields, but it varies in intensity, apparently increasing from the southwest to the northeast, yet there are no doubt local variations from the general conditions, so that both fields should be carefully prospected to discover the coal beds that are least disturbed. Such prospecting has been begun by the Navy Department for the Matanuska field and should be done in the Bering River field.

As a result of this great disturbance nearly all the coal beds are tilted, many at high angles, and some are folded and overturned. Although the folding is far more complex than that of the Pennsylvania anthracite, it is no greater than that of some of the coal beds mined in Europe.

In addition to the folding there is much faulting, which is far more serious to the miner. Faults are of two general types—cross faults, which cut across the beds, and bedding or parallel faults, which follow the bedding of the strata and of many of the coal beds themselves. These two types merge into each other so that by change of direction a cross fault may become a bedding fault and vice versa.

The best-known example of cross faulting is in the Eska mine, where the displacement in at least one locality amounts to several hundred feet. If the cross faults are clean breaks they do not seriously interfere with the mining of coal, though they do greatly increase the cost of mining because of the large amount of deadwork required to pick up the coal bed beyond the fault.

Far more serious are the bedding faults, which, so far as present developments show, are characteristic structural features of much of the areas of best coal. Evidence is abundant to show that the bedding faults are usually developed from cross faults, which enter the coal bed, follow it as bedding faults for a certain distance, and leave it as cross faults. Where a fault follows a coal bed the bed thickens and thins very irregularly and may be practically squeezed out. Moreover, many of the bedding faults are not the results of movements along a single plane, but include a complex of fault planes. This type of fault is marked by a zone of crushing, which may include not only the entire coal bed but a part of the wall rock, so that the position of the coal bed is marked by a complex mixture of coal and wall rock. These

bedding faults appear at irregular intervals and differ in extent. As a result of such faulting a bed of good coal that has been followed by a gallery for several hundred feet may suddenly be lost or may pass into a zone made up of intermingled coal, shale, and bone that can not be separated in mining. In the mining thus far done no coal bed has been traced unbroken for more than 500 feet.

In places the difficulties of mining are further enhanced by the presence of intrusive dikes or stocks of igneous rocks. In the Bering River field there are no stocks and so far as determined the dikes are not sufficiently abundant to interfere seriously with mining. In the Matanuska field dikes are far more numerous and large dioritic stocks cut the coal measures. The gaseous character of these coals, the local differences in the firmness of the wall rock, and other physical conditions also influence the cost of mining, but these will not be considered here.

The discouragement found in the facts presented above is offset by the encouragement afforded by certain other facts: (1) The coal is of better grade than any other found on the Pacific seaboard; (2) outcrops of such coal are distributed over an area of about 70 square miles in the two fields; (3) it is quite possible that the parts of the fields in which the structural conditions are most favorable to mining have not been revealed; (4) underground work has thus far been limited to a total of about 21,500 feet of gangways and crosscuts and to tracts aggregating only a few square miles, and even these tracts have not been exhaustively explored.

The above outline indicates the principal difficulties, as well as the advantages and favorable possibilities, in mining Alaska coal. The difficulties are inherent in the mode of occurrence of the coal, and added to them are the difficulties inherent in all operations in remote regions, such as that of obtaining transportation and labor. It should be noted also that though there will undoubtedly be a great demand for the coal no actual market has yet been definitely established. The Government railroad gives ready access to the Matanuska field, but a large investment will be required for railroad construction into the Bering River field. Moreover, to reach a market in the States will require proper ocean carriers, which do not now form a part of the Alaska merchant marine. It is therefore evident that large investments will be necessary and that much time must pass before any expectation of a large coal-mining industry in Alaska can be realized; also that private capital will not undertake the development of the industry unless there is hope for very large returns. The greatest liberality must therefore be shown to coal lessees unless the Government itself is to undertake the underground exploration.

Coal produced in Alaska, 1888 to 1920.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1888–1896	6,000	$84,000	1910	1,000	$15,000
1897	2,000	28,000	1911	900	9,300
1898	1,000	14,000	1912	355	2,840
1899	1,200	16,800	1913	2,300	13,800
1900	1,200	16,800	1914	....	....
1901	1,300	15,600	1915	1,400	3,300
1902	2,212	19,048	1916	13,073	52,317
1903	1,447	9,782	1917	53,955	265,317
1904	1,694	7,225	1918	75,606	411,850
1905	3,774	13,250	1919	60,674	343,547
1906	5,541	17,974	1920	61,111	355,668
1907	10,139	53,600			
1908	3,107	14,810		313,788	1,796,128
1909	2,800	12,300			

Coal consumed in Alaska, 1899–1920, in short tons.

Year.	Produced in Alaska, chiefly subbituminous and lignite.	Imported from States, chiefly bituminous from Washington.	Total foreign coal, chiefly bituminous from British Columbia.	Total coal consumed.
1899	1,200	10,000	[a] 50,120	61,320
1900	1,200	15,048	[a] 56,623	72,871
1901	1,300	24,000	[a] 77,674	102,974
1902	2,212	40,000	[a] 68,363	110,575
1903	1,447	64,626	[a] 60,605	126,678
1904	1,694	36,689	[a] 76,815	115,198
1905	3,774	67,713	[a] 72,612	144,099
1906	5,541	69,493	[a] 47,590	122,624
1907	10,139	46,246	[a] 93,262	149,647
1908	3,107	23,893	[a] 86,404	113,404
1909	2,800	33,112	69,046	104,958
1910	1,000	32,098	58,420	91,518
1911	900	32,255	61,845	95,000
1912	355	27,767	68,316	96,438
1913	2,300	69,066	56,430	127,796
1914	....	41,509	46,153	87,662
1915	1,400	46,329	29,457	77,186
1916	13,073	44,934	53,672	111,679
1917	53,955	58,116	56,589	168,660
1918	75,606	51,520	37,986	165,112
1919	60,674	57,166	48,708	166,548
1920	61,111	37,043	45,264	143,418
	304,788	928,623	1,321,954	2,555,365

[a] By fiscal year ending June 30.

PETROLEUM.

The petroleum produced in Alaska in 1920, as in previous years, was derived from the single patented claim in the Katalla oil field. This property is owned by the Chilkat Oil Co., which refines the entire product in its own refinery. The output in 1920 was pumped from 7 or 8 small wells. Two new wells in which oil was found were drilled on this property in 1920. The high-grade gasoline made from this oil finds a ready sale in the local market, chiefly on Prince William Sound. At present the residue from the refinery is not utilized

No drilling was done in undeveloped fields in 1920, but some geologic examinations were made by private corporations. In 1920–21

a hole was sunk near Anchorage to a depth of about 200 feet, but did not reach bedrock. Later (July, 1921) a small petroleum seepage was found near Anchorage in the gravel and clay which here mark the bedrock. The alluvial cover prevents the determination of the bedrock source of the oil.

The enactment of the oil-land leasing act of February, 1920, together with the world-wide search for petroleum, has again attracted public attention to the oil lands in Alaska, which had been withdrawn from entry since 1910. The enactment of the new law started a rush into all the accessible prospective oil fields, and many claims were staked. Later the enthusiasm of this rush carried many of the locators into areas that had little to recommend them as possible fields for petroleum. Up to the end of the year 335 applications for oil-prospecting permits, covering 762,553 acres, had been received at the Juneau land office. These applications, according to Mr. Stewart,[12] are distributed geographically as follows:

Applications for oil permits received at Juneau land office, 1920.

Location.	Number.	Area (acres).
Cold Bay	168	431,040
Katalla	63	98,053
Yakataga	36	75,520
Iliamna (Iniskin Bay)	30	69,400
Kootznahoo (Admiralty Island, southeastern Alaska)	15	33,280
Cape Spencer (Icy Strait, southeastern Alaska)	3	7,680
Chinitna, (north of Iliamna Bay, Cook Inlet)	3	7,680
Seward (Kenai Peninsula)	2	5,320
Wasilla (Matanuska Valley)	2	5,120
Anchorage (Knik Arm)	9	19,200
Aniakchak (Alaska Peninsula, southwest of Cold Bay)	4	10,240

Of the above list, only the Cold Bay, Katalla, Yakataga, Iliamna, and possibly the Chinitna and Aniakchak areas are classed by the Geological Survey as prospective oil territory on the geologic information now at hand.[13] Curiously enough, no claims appear to have been filed on any land in the Douglas River region, tributary to the southwest end of Cook Inlet, where an oil seepage has long been known.

The large areas staked in the prospective oil fields above listed no doubt include much land that is worthless, but until the structure has been worked out this can not be helped. It will be well to note also that until actual drilling has been done there is no certainty of the existence of important oil pools in any of these areas. Some drilling will probably be done in 1921, but these prospective fields can probably not be systematically tested for several years.

[12] Stewart, B. D., Annual report of the Territorial mine inspector to the governor of Alaska, 1920, p. 11, Juneau, 1921.

[13] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, 1921.

Petroleum products shipped to Alaska from other parts of the United States, 1905–1920, in gallons.[a]

Year.	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation.	Illuminating oil.	Lubricating oil.
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
1917	23,971,114	3,256,870	750,238	465,693
1918	24,379,566	1,086,852	382,186	362,413
1919	18,784,013	1,007,073	3,515,746	977,703
1920	21,981,569	1,764,302	887,942	412,107
	259,931,061	25,369,708	12,695,150	4,012,640

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1920, Bureau of Foreign and Domestic Commerce.

STRUCTURAL MATERIALS, ETC.

Marble is widely distributed in southeastern Alaska[14] but has been developed on an extensive scale only at the quarries of the Vermont Marble Co. at Tokeen, near the north end of Prince of Wales Island. In 1920, as in the past, only one gypsum mine was operated in Alaska. The mine was flooded during the first four months of the year, but operations were resumed later on the same scale as before.

The equipment for mining and reducing sulphur on Akun Island, at the east end of the Aleutian chain, was completed about the end of the year, but no sulphur has yet been produced there.

A trial shipment of about 20 tons of garnet sand, taken from the beach of Imuruk Basin, 20 miles east of Port Clarence, to be used as an abrasive, was made from Nome in the summer of 1920.

REVIEW BY DISTRICTS.

The following review summarizes briefly the principal developments in all the districts. Many of the districts were not visited by members of the Geological Survey in 1920, and for this reason and because some operators fail to make reports the information at hand is not complete, especially concerning the placers of the lower Kuskokwim basin and of the Koyukuk district. The space devoted to any district is therefore not necessarily a measure of its relative importance. The general arrangement of the presentation is geo graphic, from south to north.

[14] Burchard, E. F., Marble resources of southeastern Alaska: U. S. Geol. Survey Bull. 682, 1920.

SOUTHEASTERN ALASKA.

The mineral output of southeastern Alaska in 1920 was derived from eight gold-lode mines, gold placers (a very small production), two copper mines, one of which yields ore carrying a high content of platinum minerals, one gypsum mine, and one large marble-quarry property. The total value of the minerals produced increased from $4,679,632 in 1919 to $5,120,163 in 1920. Only four of the gold mines were large producers—three at Juneau and one on Chichagof Island; the others were under development and made a small incidental output of gold. All the copper produced came from the Rush & Brown and Salt Chuck mines, in the Ketchikan district. Placer mining was limited to very small operations in the Porcupine district and on the beach placers of Yakataga and Lituya Bay.

Mineral production of southeastern Alaska, 1920.

	Ore mined (tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
Gold-lode mines	3,409,197	210,535	$4,352,145	114,621	$124,937
Copper mines	15,018	913	18,873	5,313	5,791
Placer mines	....	193	3,990	33	36
	3,424,215	211,641	4,375,008	119,967	130,764

	Copper.		Lead.		Palladium, marble, gypsum, etc. (value).
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	
Gold-lode mines	....	....	1,518,454	$121,477	....
Copper mines	[a] 670,155	$123,308	....	....	....
Placer mines	....	....	....	....	....
	670,155	123,308	1,518,454	121,477	$369,606

[a] Includes some copper shipped from other parts of Alaska.

KETCHIKAN DISTRICT.

Productive development work was continued at the Rush & Brown mine on about the same scale as in previous years. This is the oldest productive copper mine in southeastern Alaska, having been operated almost continuously since 1904. In 1920, as in previous years, the work was directed principally to the development of the smaller of the two ore bodies that have been explored underground. This ore body lies in a shear zone bounded by two well-defined walls of graywacke. It consists of rich chalcopyrite ore shoots in a mineralized gangue of crushed graywacke, which is in part merchantable ore, for in addition to the rich shoots the gangue contains veins and veinlets of sulphides. The ore body contains also some pyrite and pyrrho-

tite. The lower-grade copper-bearing magnetite ores on the property, of which a considerable tonnage has been developed, will not be utilized until a market for their iron content can be found. The Ketchikan district as a whole has large reserves [15] of this type of ore, which will form an important asset when use can be found for its iron content. The principal work on the Rush & Brown mine in 1920 was the extension of the incline to the 500-foot level, drifting on the 450-foot level, and explorations at higher levels. All the ore produced was sent to the Anyox smelter, in British Columbia. Mining was done at the Salt Chuck mine on a larger scale in 1920 than in the previous year. The ore on this property has a high content of palladium and platinum and carries copper also. This occurrence was fully described in the report of last year.[16]

The Dunton gold mine, near Hollis, on Prince of Wales Island, has been taken over by the Kasaan Gold Mining Co., and the name of the property has been changed to Harris Creek mine. The ore body has been described in a recent publication.[17] In 1920 the work has consisted chiefly of a reconstruction of the mill and mining plant, which was completed in the fall of 1920. Some gold ore was milled in the course of the year. Considerable prospecting was done by the Helm Bay Mining Co. on a group of claims on Helm Bay, on the south shore of Cleveland Peninsula, north of Ketchikan. The group includes the old Gold Standard mine, which has not been worked for many years. The work performed in 1920 includes a series of shallow open cuts and pits, which crosscut a rather ill-defined shear zone traversing greenstone schists. Within this shear zone there are many small quartz veins and stringers which carry gold and some pyrite. The zone has been traced with some interruptions for several thousand feet. The several open cuts show from 10 to 50 feet of mineralized rock, but no well-defined walls were seen. It is reported that results of sampling seven or eight of these cuts yielded an average of about $6 worth of gold to the ton. A crosscut is being driven, which should reach the shear zone at a depth of 80 feet. The work on this property when it was hastily examined in September, 1920, was only well begun, as the bedrock was exposed only in the open cuts. No adequate conception of the character of the ore body could be obtained. The value of the property will depend on the quantity of ore, which, according to the surface indications, may be large. Another important fact that awaits determination is the continuance in depth of the gold content thus far reported. The cuts examined showed some oxidation, which indicates that there may be some surface enrichment. The evidence at other mines in the district supports the

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[15] Brooks, A. H., The future of Alaska mining: U. S. Geol. Survey Bull. 714, pp. 15-19, 1921.

[16] Mertie, J. B., jr., Lode mining in the Juneau and Ketchikan districts: U. S. Geol. Survey Bull. 714, pp. 121-217, 1921.

[17] Idem, pp. 127-128.

belief that a crosscut run on the ore body at a depth of 80 feet should give a reliable indication of the depth of surface enrichment.

JUNEAU DISTRICT.

The Perseverance, Alaska-Juneau, and Ready Bullion mines and mills, all near Juneau, were operated throughout the year. In 1920 the value of the average recovery of metal from the ore of these three mines was 85 cents a ton. Developments were continued throughout the year on the Alaska Ebner property, adjacent to the Alaska-Juneau. This mine is developed by an adit 4,000 feet long, and during 1920 about 1,000 feet of drifting and crosscutting was done.

Developments at the Jualin mine, at Berners Bay, were suspended in February, 1920, but the company reports that work will be resumed when financial conditions improve. The 10-stamp mill at this mine was burned during the year, but the extensions projected include a 200-stamp mill. A little work was done at the Peterson mine, north of Juneau. Some work was done at the Daisy Bell mine, near Snettisham, and a little ore was treated in its 5-stamp mill.

The following notes on the most important recent developments at Windham and Sumdum bays are taken from Stewart's report.[18] In 1919 the Alaska Peerless Mining Co. drove about 50 feet of adits and crosscuts on the Basin Queen lode, at Windham Bay. This property, formerly known as the Yellow Jacket group, has been described by Spencer.[19] This work exposed an extensive belt of highly mineralized talcose schist approximately 70 feet in width, constituting a showing which appears to be well worth further exploration. The main tunnel is now 400 feet in length, and from it four crosscuts have been driven aggregating 300 feet. It was planned by the Alaska Peerless Mining Co. to drive a crosscut adit 630 feet vertically below the present drift adit and 5,000 feet in length, to cut the above-described zone at this horizon. This work was started and 50 feet of open-cut work and 30 feet of tunneling work completed. Work on the property was discontinued in the fall of 1919 and only assessment work done during 1920.

According to the mine inspector's report, the Independent Gold Mining Corporation completed in 1920 about 150 feet of underground work on a property at the head of Windham Bay. The ore body exposed is a belt of silicified schists, having an average width of about 10 feet and containing gold, galena, and iron sulphides. This mineralized belt has been traced on the surface for a long distance to the southeast of the adit and it crops out on the opposite shore of the bay, where claims have been located upon it.

The most extensive developments on Admiralty Island were those made on the property of the Admiralty Alaska Gold Mining Co.,

[18] Stewart, B. D., Annual report of Territorial mine inspector to the governor of Alaska, 1920, p. 30, Juneau, 1921.

[19] Spencer, A. C., The Juneau gold belt: U. S. Geol. Survey Bull. 287, p. 41, 1906.

which has been described in a recent report.[20] Here operations were carried on from May to the end of the year. The main adit was extended for about 650 feet. Many open cuts were made, and a new working shaft was started. Work was continued in a small way on the Nowell-Otterson group of claims,[21] which are adjacent to the Admiralty-Alaska property.

Underground work has been continued at the Alaska Endicott property on William Henry Bay, north of Juneau. Preparations are being made to erect a mill and compressor plant.

SITKA DISTRICT.

The Sitka district was the scene of the first lode-gold mining venture in Alaska, which began as early as 1871. This proved unprofitable, and when gold was discovered at Juneau and on the Yukon the district was almost abandoned. It was not until 1905, when the Chichagoff lode, now developed into one of the largest mines in Alaska, was discovered, that prospectors began to return to the district. In 1920 lode prospecting was more active here than in any other part of the Territory and some promising discoveries were made. It is astonishing that a region which is so readily accessible and in which the physical conditions permit low operating costs should have been almost ignored for nearly half a century.

In 1920, as in the past, the Chichagoff mine was the only productive property in the district except the gypsum mine already referred to (p. 33). The mine and 30-stamp mill were operated throughout the year, and the new underground work included 112 feet of shaft and 1,310 feet of drifts.

The following quotation from the Territorial mine inspector's report summarizes the recent prospecting in the Sitka district:[22]

> Active development was continued on the Hirst-Chichagoff property, at Hirst Cove, on the opposite side of Doolth Mountain from the Chichagoff mine.
>
> During the winter of 1919 and the spring of 1920 a stamp mill which had been installed at Windham Bay was dismantled and moved to the Hirst-Chichagoff property. A mill building was constructed, but the mill has not yet been installed.
>
> A wharf has been built and a comfortable bunk house and boarding house completed at the property. Difficulty was had with the compressor formerly in use, and a new machine has been installed. Following this improvement work was resumed on the crosscut tunnel at the mill level, and about 300 feet driven, making a total of about 1,100 feet. It is understood this tunnel has reached the vein and exploration of the ore zone at the mill tunnel level has begun. This vein is very similar in type to the Chichagoff vein, and the results of development work upon it are being looked forward to with interest.
>
> The Chichagoff Mining Co. has acquired control of the Apex group of claims, lying across the divide, between the head of Cann Creek on the west shore of Lisianski Inlet and Stag Bay, an arm of Lisianski Strait.

[20] Mertie, J. B., jr., Mining in Juneau and Ketchikan districts: U. S. Geol. Survey Bull. 714, pp. 115-116, 1921.

[21] Idem, pp. 116-118.

[22] Op. cit., pp. 22-23.

The discovery of the Apex vein was made in October, 1919, and development work was commenced upon it as soon as the snow had left in the early summer of 1920. The vein on the surface averages about 20 inches in width, and its outcrop has been traced for a considerable distance. Patches of exceedingly high grade gold ore appear on the outcrop at several places.

A camp was built on the beach at the mouth of Cann Creek and a pack trail about 2 miles in length constructed, leading to an upper camp and the lowest showings on the outcrop. The upper camp is at an altitude of 800 or 900 feet and the discovery about 1,300 feet. It is understood that a tunnel 50 feet in length has been driven on the vein, commencing at the discovery, since July, 1920. A lower tunnel, commencing at a point near the upper camp, is understood to be under construction at the present time.

The Apex vein is practically solid quartz in unaltered hornblende diorite. A very fine grained porphyritic acidic dike a few inches in thickness lies along the walls on either side of the vein. This dike closely resembles quartzite in appearance and weathers brown on the surface.

Adjoining the Apex group on the east is the El Nido group of claims, controlled by Mr. J. H. Cann, who was also one of the discoverers of the Apex lode. The El Nido lode was discovered in June, 1920, and some development work, consisting of open cuts and trenching, had, at the time of visit (July, 1920), exposed the outcrop for a length of about 200 feet. Some exceedingly high grade samples were secured from this crop, hand specimens being said to run as high as $5 per pound. The El Nido lode at the outcrop is from 3 to 3½ feet in width, consisting of alternating pure white quartz and dike material, similar to that referred to above in connection with the Apex lode. No report has been had on developments made on this lode since July, 1920.

COPPER RIVER BASIN.

The continuous operation of the three large copper mines of the Kennecott group and the summer placer mining in the Nizina and Chistochina districts constitute all the productive work done in the Copper River basin in 1920. A little underground work was done on the Midas gold mine [23] in the early part of the summer, but the mill was not operated. The only other lode operations were assessment work on copper claims.

The following statements on mining and milling at the Kennecott group of mines during 1920 are taken from the annual report of the company:[24]

Kennecott ores milled totaled 199,656 tons, assaying 6.82 per cent. From this tonnage there resulted 21,696 tons concentrates assaying 51.06 per cent copper, this giving a recovery of 82.29 per cent, as against 85.9 per cent in 1919 and 84.19 per cent in 1918. The percentage of total copper occurring in carbonate form was 41.8, compared with 37.4 in 1919 and 37.8 in 1918, which accounts for the lower recovery obtained during the last year. The cost per ton of milling was 76 cents, as against 73 cents in 1919 and 80 cents in 1918.

In addition to the Kennecott ores the Kennecott mill also treated 67,567 tons of ore during the year for the account of the Mother Lode Coalition Mines Co.

The leaching plant at Kennecott treated 190,327 tons mill tailings assaying 1.14 per cent carbonate copper, with a recovery of 3,332,500 pounds of copper in the form of

[23] For a brief description of the ore body see Moffit, F. H., Mining in the Chitina Valley: U. S. Geol. Survey Bull. 714, pp. 191-192, 1921.

[24] Kennecott Copper Corporation Sixth Ann. Rept., for year ending December 31, 1920, pp. 6-7, New York, 1921.

precipitates assaying 74.75 per cent copper, the percentage of recovery being 74.5 per cent, as against 74 per cent in 1919. Leaching costs were $1.33, as against $1.18 in 1919 and $1.12 in 1918.

The total recovery of copper in all ores treated, milling and leaching combined, was 90.10 per cent, as against 92.96 per cent in 1919 and 89.38 per cent in 1918.

Thirteen thousand six hundred and thirty feet of development work was driven for the purpose of developing new ore bodies and opening known deposits on other levels preparatory to stoping. In addition to this 14,936 feet of diamond drilling was done. The most important items were the development of the Birch vein, on the 150-foot level, and the Bonanza-Mother Lode vein, on the 900-foot level in the Bonanza mine; and in the Jumbo mine, the development of the ore in the 518 vein at and below the fifth level.

The work of building the Glacier mine tramway was completed in time to transport 4,722 tons that were mined before the season closed. At the same time an intermediate station at the halfway station of the Jumbo line was built, making it possible to handle a greater tonnage over this line.

A high-tension power line was strung to the Erie mine, making it possible to use compressed air in carrying on the development of this mine.

In 1920, as in previous years, practically all the placer gold produced in the Nizina district was obtained from three hydraulic mines on Dan, Chititu, and Rex creeks. A little mining was also done on the bench placers of Dan Creek.

Nine placer mines were operated in the Chistochina district during the summer of 1920, employing 35 men and producing gold to the value of about $75,000. The largest output was made by a hydraulic plant on Slate Creek. An average of $1.53 worth of gold per cubic yard was recovered from the placer-mining operations of the district. Some platinum was won from the Slate Creek placers.

Some placer mining was done in the Nelchina and Valdez Creek districts, and plans are under way for again operating the large hydraulic plant on Valdez Creek, which has been idle for several years.

PRINCE WILLIAM SOUND.

Mining was at a low ebb in the Prince William Sound region[25] during 1920, except for the large copper output of the Beatson mine, on Latouche Island. Other mines, however, incidentally produced some copper. The only gold mine on Prince William Sound that reported any production in 1920 was the Valdez Gold, which produced only a few tons of ore.

The following extracts from the annual report of the Kennecott company summarize the principal operations at the Beatson mine during the year. Much work was done at the Girdwood mine, which is north of and adjacent to the Beatson. The mine is developed by a 1,600-foot adit and is equipped with a 150-ton flotation mill.

Ore milled totaled 451,863 tons, assaying 1.77 per cent copper. From this tonnage 44,268 tons of concentrates were produced, assaying 15 per cent copper, as against

[25] The ore deposits of Prince William Sound are described in the Geological Survey reports listed on pages v and vi.

264,265 tons milled, 28,204 tons concentrates produced, assaying 14.78 per cent, in 1919. The average recovery was 82.85 per cent, as against 80.8 per cent in 1919; however, the recovery of copper existing as the sulphide in the ore was 85.2 per cent.

Two thousand nine hundred and fourteen feet of raising and 5,738 feet of drifting, making a total of 8,652 feet, augmented by 4,846 feet of diamond drilling, was done during the year. This work, with the exception of 1,499 feet of raising and drifting and 991 feet of diamond drilling done on the upper levels, was for the purpose of preparing the ore above the 200 level for stoping.

A small sawmill was added to the surface equipment. A compressor of 500 cubic feet capacity was added to furnish air for the mill. A mechanical shoveler was purchased to be used underground.

The Schlosser mine of the Alaska Mines Corporation was operated from January 1 to November 15. The hand-sorted crude ore is shipped to the Tacoma smelter. In 1920 the principal advance work done was that of driving 1,450 feet of the main adit.

The work done at the Fidalgo (McIntosh) mine on Fidalgo Bay included the driving of a 104-foot raise and a 150-foot drift, in course of which some ore was recovered, but none was shipped.

Copper prospecting on Knight Island is practically at a standstill. The only development was the continuation of the main crosscut on the Rua Cove property by W. A. Dickey.

The Valdez Mining Co. continued to develop its property [27] on the west side of Valdez Glacier from June until December, 1920. The main adit was driven 400 feet during the year and is now 800 feet long. Some ore that was recovered incidentally to the development work was milled. Late in the summer of 1920 the Cliff mine, near Valdez, was unwatered, and about 119 feet of underground work was done. The ore body has been described by Johnson.[28]

KENAI PENINSULA.

There was no improvement in gold mining on Kenai Peninsula during the year. The value of the total mineral output in 1920 was $35,000, and that in 1919 was $37,500. Of the total amount for 1920 $14,675 is to be credited to the gold output of two small lode mines and six placer mines, the latter employing about 15 men. Most of the placer gold came from Resurrection, Canyon, and Sixmile creeks.

The Lucky Strike mine, on Palmer Creek, was operated from June to October, and its mill for 15 days, one shift a day. The principal underground work done consists of a 150-foot adit. Some ore was milled at the Virginia mine, but no developments were made. There was considerable prospecting of auriferous quartz veins during the year. Plans were made for doing work on a group of quartz claims at the head of Crow Creek, on the north side of Turnagain Arm.

[27] For a brief description of the ore body see Johnson, B. L., The gold and copper deposits of the Port Valdez district: U. S. Geol. Survey Bull. 622, p. 162, 1915.

[28] Idem, pp. 170-172.

These claims, so far as identified, belong to what was formerly known as the "Barnes property," which has been described in a former report.[29]

The operation of the lignite mine at Bluff Point, on Kachemak Bay, and the developments on chrome deposits at Red Mountain have already been referred to (pp. 26, 24).

SUSITNA AND MATANUSKA REGION.

Productive mining in the Susitna-Matanuska region included gold-placer mining in the Yentna district and at a few scatterred places in the Susitna basin, gold-lode mining in the Willow Creek district, and coal mining in the Matanuska field and at one or two other places in the Susitna basin. The value of the total mineral output from this region was $532,562 in 1919 and $324,810 in 1920. Most of the decrease in 1920 was due to the decline in the output of gold. The consolidation of some of the Willow Creek gold properties and the systematic exploration of the Matanuska coal field constitute the most important advances of the year. The developments in coal mining have already been summarized (pp. 25, 26).

WILLOW CREEK DISTRICT.

Productive mining was done on three properties in the Willow Creek district in 1920. These were the Mabel mine, the Gold Bullion mine, and the Independent, Brooklyn, and Free Gold mines, consolidated into one holding by the Kelly Mines Co. Lode mining in this district has heretofore been done in a small way on properties worked only during the open season, and the several small mills were built at altitudes so high that they could obtain water only during the summer. Since mining began, in 1908, the district has produced 66,053 tons of ore, from which the average value of gold recovered has been $27.70 per ton and the silver recovery 0.1 ounce per ton. These figures do not, however, represent the whole value of the ores, for the gold is largely free gold, recovered by rather crude milling practice. Thus far little of the concentrates has been utilized. Larger operations have now been planned and an increase in the output of gold can be confidently expected.[30]

The following table shows the progress and results of lode mining in the Willow Creek district. In addition to the production of lode

[29] Johnson, B. L., The central and northern part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 173-176, 1915.

[30] The ore bodies of the Willow Creek district are described in the folowing publications:

Capps, S. R., The Willow Creek district: U. S. Geol. Survey Bull. 607, 1915; Gold mining in the Willow Creek district [1915]: U. S. Geol. Survey Bull. 642, pp. 195-200, 1916; Gold-lode mining in the Willow Creek district [1917]: U. S. Geol. Survey Bull. 692, pp. 177-186, 1919.

Chapin, Theodore, Lode developments in the the Willow Creek district [1918]: U. S. Geol. Survey Bull. 712, pp. 169-176, 1920; Lode developments in the Willow Creek district [1919]: U. S. Geol. Survey Bull. 714, pp. 201-206, 1921.

gold about $30,000 worth of placer gold has been taken from the gravels of Willow Creek. A little placer mining was done in this field as early as 1897, but no output has been made from these placers during the last 10 years.

Gold and silver produced at lode mines in the Willow Creek district, 1908–1920.

Year.	Mines operated.	Ore mined (short tons).	Gold.		Silver.	
			Quantity (ounces).	Value.	Quantity (ounces).	Value.
1908	1	12	87.08	$1,800	6.88	$3.64
1909	1	140	1,015.87	21,000	80.25	41.73
1910	1	144	1,320.15	21,290	104.29	56.31
1911	2	812	2,505.82	51,800	197.95	109.91
1912	3	3,000	4,673.02	96,600	369.07	226.97
1913	3	3,028	4,883.94	100,960	385.83	233.42
1914	3	10,110	14,376.28	297,184	1,330.00	735.00
1915	3	6,117	11,961.55	247,267	811.00	421.00
1916	3	12,182	14,473.46	299,193	1,468.00	967.00
1917	5	7,885	9,466.17	195,662	713.00	586.00
1918	5	13,043	13,043.05	269,624	724.00	724.00
1919	5	6,730	7,882.00	162,944	508.00	509.00
1920	3	2,850	3,067.00	63,400	148.00	158.00
		66,063	88,755.39	1,828,724	6,846.27	4,771.98

YENTNA DISTRICT.

Only about half the placer-mining operators in the Yentna district made complete returns in 1920, but it is estimated that 21 placer mines, employing 55 men, were operated in this district during the year, and that they produced gold having a value of $45,000. The value of the output of gold in 1919 was $95,000. The length of the mining season in 1920 was about 150 days, but the mines were operated for an average of only 92 days. The returns from 7 mines, of which 5 were hydraulic, showed that the value of the gold recovery per cubic yard ranged from 40 cents to $2 and averaged 70 cents.

Several hydraulic plants are being installed in the district, and a hydroelectric plant is being built to furnish power for the Cache Creek dredge, which has not been operated in two years. The completion of the Talkeetna-Cache Creek wagon road, now under construction by the Alaska Road Commission, will do much to revive mining in the Yentna district.

UPPER SUSITNA VALLEY AND BROAD PASS REGION.

No productive mining was done in the upper Susitna Valley nor in the Broad Pass region in 1920 except the digging of a little lignitic coal for local use at Sullivan Road House and possibly a little placer mining at widely scattered localities. Interest in the gold and copper lodes of this region has continued, and in the aggregate considerable development work was done, but the details are lacking at this writing.

SOUTHWESTERN ALASKA.

No productive mining was done in southwestern Alaska in 1920 except small beach-placer operations on Kodiak Island. The development of the sulphur on Akun Island has already been recorded (p. 33), as well as the staking of petroleum claims in the Cold Bay and other regions of the Alaska Peninsula (pp. 131–132).

YUKON BASIN.

The value of the total mineral output of the Alaska Yukon region in 1920 was $2,329,286; the value in 1919 was $3,049,061. No encouraging advances were made during the year except some development of gold and silver lodes in the Kantishna district and the systematic mining of coal in the Nenana field. The sources of the product in 1920 and the total mineral production since mining began, in 1886, are presented in the following tables:

Mineral production of the Yukon basin, Alaska, in 1920.

	Placer mines.		Lode mines.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold....fine ounces..	96,508	$1,995,000	2,585	$53,447	99,093	$2,048,447
Silver....do....	12,905	14,068	131,276	143,090	144,181	157,158
Tin, metal....pounds..	11,057	3,454	....	....	11,057	3,454
Coal....tons..	....	....	....	....	21,252	107,418
Lead and copper....	....	....	....	12,809	....	12,809
	....	2,012,532	....	209,346	....	2,329,286

Mineral production of the Yukon basin, Alaska, 1886-1920.

	Placer mines.		Lode mines.		All mines.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold....fine ounces..	6,305,858	$130,352,000	62,364	$1,288,677	6,368,222	$131,640,677
Silver....do....	1,083,447	656,390	150,030	152,012	1,233,477	808,402
Tin, metal....pounds..	327,467	162,194	....	....	327,467	162,194
Coal....tons..	....	....	....	....	42,851	253,621
Lead and copper...pounds..	....	....	275,321	14,481	275,321	14,481
Antimony, tungsten, and platinum....	....	3,100	....	325,500	....	328,600
	....	131,173,684	....	1,780,670	....	133,207,975

In 1920 the Alaska Yukon region produced about $1,995,000 and in 1919 $2,910,000 worth of placer gold. The decrease in output was rather evenly distributed among all the districts except the Ruby district, which practically maintained its output of 1919. The Tolovana district showed the greatest percentage of loss as compared with previous years. About 273 placer mines, giving employment to about 1,130 men, were operated during the summer of 1920, and 69, giving employment to 270 men, were operated during the previous

winter. A very large number of these mines were worked for only a part of the season. In 1919 274 mines, employing 1,246 men, were worked in the summer and 76, employing 255 men, in the winter.

Estimated value of gold produced from principal placers of Yukon basin, 1920.

Fairbanks	$580,000	Marshall	$90,000
Iditarod	505,000	Circle	55,000
Tolovana	200,000	Hot Springs	50,000
Ruby	170,000	All others	152,000
Innoko and Tolstoi	103,000		
Koyukuk	90,000		1,995,000

FAIRBANKS DISTRICT.

The value of the total mineral production of the Fairbanks district in 1920 was $605,998, represented entirely by gold and silver, for no other metals were mined. The total mineral output of the district to date is $72,650,767. The output for 1920 was practically all obtained from placer mines (see subjoined table), about 45 of which, employing 345 men, were operated in the summer of 1920 and 9, employing 54 men, in the previous winter. During the summer of 1919 there were in operation 53 mines, employing 350 men, and during the previous winter 24 mines, employing 86 men.

Placer gold and silver produced in the Fairbanks district, 1903–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903	1,935.00	$40,000	348	$188
1904	29,026.00	600,000	5,225	2,821
1905	290,250.00	6,000,000	52,245	28,212
1906	435,375.00	9,000,000	78,367	42,318
1907	387,000.00	8,000,000	69,660	37,616
1908	445,050.00	9,200,000	79,909	43,151
1909	466,818.75	9,650,000	84,027	45,375
1910	295,087,50	6,100,000	53,116	28,683
1911	217,687.50	4,500,000	52,245	27,690
1912	200,756.25	4,150,000	48,182	29,632
1913	159,637.50	3,300,000	20,274	12,245
1914	120,937,50	2,500,000	29,024	16,050
1915	118,518.75	2,450,000	28,444	14,421
1916	87,075.00	1,800,000	11,058	7,276
1917	63,371.25	1,310,000	8,379	6,904
1918	38,700.00	800,000	5,708	5,708
1919	35,313.75	730,000	5,197	5,820
1920	28,057.50	580,000	3,870	4,218
	3,420,596.25	70,710,000	635,278	358,329

The placer mines can be classed as follows: One dredging company, operating 2 dredges; 22 open-cut mines, using steam scrapers; 2 hydraulic mines; 7 open-cut mines, worked by pick and shovel; and 13 deep mines, worked by thawing and drifting. The two dredges on Fairbanks Creek carried on the largest single operation. The largest

of the open-cut mines were on Goldstream Creek and its tributaries. The 13 deep mines produced gold to the value of about $150,000.

An attempt has been made in the following table to distribute the total placer-gold production of the Fairbanks district by the creeks on which the mines are located, although the information available as to the source of the gold may not be very accurate.

Approximate distribution of gold produced in the Fairbanks district, 1903–1920.

Cleary Creek and tributaries	$23,098,000
Goldstream Creek and tributaries	14,625,000
Ester Creek and tributaries	11,359,000
Dome Creek and tributaries	8,149,000
Fairbanks Creek and tributaries	7,857,000
Vault Creek and tributaries	2,665,000
Little Eldorado Creek	2,269,000
All other creeks	688,000
	70,710,000

About 386,000 cubic yards of gravel, having an average gold content of $1.50 to the cubic yard, was sluiced in the Fairbanks district in 1920. The returns made by seven of the thirteen deep mines were nearly enough complete to permit the following analysis. These mines were operated for an average of 240 days, two of them throughout the year. They employed an average of 6.5 men each. They hoisted in all 32,600 cubic yards of gravel, from which $134,000 worth of gold was sluiced. The value of the gold content of the gravel per cubic yard ranged from $2.46 to $8.27 and averaged $4.11. The gravel mined per man per day, including surface and underground employees, ranged from 0.73 to 3.25 cubic yards and averaged 2.59 cubic yards.

The large open-cut mines in the Fairbanks district were operated on an average for 130 days. The returns from these mines are not nearly enough complete to permit a determination of the average gold recovery, but if the hydraulic mines are included and not the dredges, it ranged from 54 cents to $1.78 a cubic yard.

There was little development of the auriferous lodes in the district during 1920, nor were any discoveries reported. Work was continued in a small way at the Crites & Feldman and Billy Sunday (Smith & McGonnigle) properties, and incidentally some ore was mined and milled. Similar but smaller operations were carried on at half a dozen other quartz properties. These activities are exceptional, for the general practice of the owners of lode property in the district is to await lower operating costs before attempting lode developments.

Lode gold and silver produced in the Fairbanks district, 1910–1920.

Year.	Crude ore (short tons).	Gold.		Silver.	
		Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	148	841.19	$17,389	106	$57
1911	875	3,103.02	64,145	582	306
1912	4,708	9,416.54	194,657	1,578	971
1913	12,237	16,904.98	349,457	4,124	2,491
1914	6,526	10,904.75	225,421	2,209	1,222
1915	5,845	10,534.91	217,776	1,796	910
1916	1,111	1,904.81	39,376	140	92
1917	1,200	2,311.38	47,781	2,217	1,826
1918	1,035	1,294.04	26,750	616	616
1919	1,384	2,026.57	41,893	378	424
1920	504	967.48	20,000	164	178
	35,573	60,209.67	1,244,646	13,910	9,095

HOT SPRINGS DISTRICT.

As will be seen from the subjoined table, the gold output of the Hot Springs district was only about half as large in 1920 as in 1919. Eleven placer mines, employing 30 men, were operated in the summer of 1920, and 4, employing 15 men, in the previous winter. The value of the average gold recovery from deep mines was about $5.50 per cubic yard. Six of these mines produced a little stream tin, the total output being 7,057 pounds. The district has produced in all 265½ tons of concentrates, containing about 336,060 pounds of metallic tin, valued at $157,695.

Placer gold and silver produced in the Hot Springs district, 1902–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1902–3	12,717.79	$262,900	1,818	$964
1904	7,038.56	145,500	1,007	584
1905	5,805.00	120,000	831	507
1906	8,707.50	180,000	1,245	843
1907	8,465.63	175,000	1,210	798
1908	7,256.25	150,000	1,038	550
1909	15,721.88	325,000	2,248	1,169
1910	15,721.88	325,000	2,248	1,169
1911	37,974.37	785,000	5,430	2,932
1912	19,350.00	400,000	3,267	2,009
1913	19,350.00	400,000	3,267	1,973
1914	36,281.25	750,000	6,125	3,387
1915	29,508.75	610,000	4,982	2,526
1916	38,700.00	800,000	6,534	4,299
1917	21,768.75	450,000	3,675	3,028
1918	7,256.25	150,000	1,225	1,225
1919	4,837.50	100,000	817	915
1920	2,418.75	50,000	567	618
	298,880.11	6,178,400	47,534	29,496

TOLOVANA DISTRICT.

A shortage of water prevails in the Tolovana district in all but very wet seasons and has hampered mining for the last two years. About 13 mines, employing 106 men, were operated during the summer of 1920, and 6 mines, employing 60 men, during the preceding winter. In 1920, as in previous years, the mines making the largest production were those of Livengood Creek.

Placer gold and silver produced in the Tolovana district, 1915–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1915	3,870.00	$80,000	321	$163
1916	33,862.50	700,000	2,813	1,851
1917	55,631.25	1,150,000	8,430	6,946
1918	42,328.12	875,000	4,060	4,060
1919	25,396.88	525,000	2,141	2,454
1920	9,675.00	200,000	819	893
	170,763.75	3,530,000	18,634	16,367

RAMPART DISTRICT.

Only small placer mines are being operated in the Rampart district. In 1920 there were 10 summer mines, employing 20 men, and 4 winter mines, employing 6 men.

Placer gold and silver produced in the Rampart district, 1896–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1896–1903	29,799.00	$616,000	4,440	$2,664
1904	4,353.75	90,000	649	376
1905	3,870.00	80,000	576	351
1906	5,805.00	120,000	865	588
1907	6,046.87	125,000	901	595
1908	3,628.12	75,000	540	286
1909	4,837.50	100,000	721	375
1910	2,080.12	43,000	310	167
1911	1,548.00	32,000	231	125
1912	1,548.00	32,000	274	169
1913	1,548.00	32,000	274	165
1914	1,451.25	30,000	257	142
1915	1,693.13	35,000	300	152
1916	1,935.00	40,000	343	226
1917	1,596.37	33,000	280	231
1918	1,161.00	24,000	206	206
1919	1,451.25	30,000	90	101
1920	967.50	20,000	69	75
	75,319.86	1,557,000	11,326	6,994

CIRCLE DISTRICT.

The output of gold in the Circle district in 1920 was only about one-third of that in 1919. About 20 mines were operated, employing some 50 men in the summer of 1920, and about 9 mines, employing 15 men, in the previous winter. The small output of gold was due partly to the closing down of the dredge and partly to a dry season, which caused a shortage of water for sluicing.

Placer gold and silver produced in the Circle district, 1894–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1894	483.75	$10,000	123	$77
1895	7,256.25	150,000	1,886	1,226
1896	33,862.50	700,000	8,794	6,080
1897	24,187.50	500,000	6,289	3,773
1898	19,350.00	400,000	5,031	2,968
1899	12,093.75	250,000	3,144	1,886
1900	12,093.75	250,000	3,144	1,886
1901	9,675.00	200,000	2,512	1,507
1902	9,675.00	200,000	2,512	1,331
1903	9,675.00	200,000	3,144	1,698
1904	9,675.00	200,000	3,144	1,823
1905	9,675.00	200,000	3,144	1,918
1906	14,512.50	300,000	3,773	2,565
1907	9,675.00	200,000	3,144	2,075
1908	8,465.63	175,000	2,212	1,166
1909	10,884.37	225,000	2,830	1,472
1910	10,884.37	225,000	2,830	1,528
1911	16,931.25	350,000	4,402	2,333
1912	15,721.87	325,000	2,439	1,500
1913	8,465.63	175,000	1,314	794
1914	10,884.37	225,000	1,689	934
1915	11,126.25	230,000	1,727	875
1916	14,512.50	300,000	2,252	1,482
1917	9,675.00	200,000	1,561	1,285
1918	8,465.63	175,000	1,798	1,798
1919	6,530.63	135,000	1,260	1,411
1920	2,660.62	55,000	464	506
	317,098.12	6,555,000	76,562	47,897

RICHARDSON DISTRICT.

Auriferous gravels are rather widely distributed in the Richardson district, in the Tanana Valley. No very rich placers have been found, and the mining consists of relatively small operations at widely scattered localities. It is estimated that eight mines, employing 18 men, were operated in the summer of 1920, and one mine, employing 3 men, was operated in the previous winter.

Placer gold and silver produced in the Richardson district, 1905–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1905	(a)	(a)	(a)	(a)
1906	4,837.50	$100,000	989	$673
1907	18,140.62	375,000	3,707	2,447
1908	18,140.62	375,000	3,707	1,965
1909	7,256.25	150,000	1,483	771
1910	4,837.50	100,000	989	534
1911	4,837.50	100,000	989	524
1912	4,837.50	100,000	989	608
1913	4,837.50	100,000	989	597
1914	4,837.50	100,000	989	547
1915	4,595.62	95,000	939	476
1916	3,870.00	80,000	790	520
1917	1,289.37	25,000	245	203
1918	290.25	6,000	59	59
1919	483.75	10,000	99	111
1920	338.62	7,000	69	75
	83,430.10	1,723,000	17,032	10,109

a Prospects.

EAGLE DISTRICT.

In the Eagle district about 10 mines, employing 25 men, were operated in the summer of 1920. There was no winter mining. Most of the productive mining was done in the Seventymile basin.

Placer gold and silver produced in the Eagle and Seventymile districts, 1908–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1908	483.75	$10,000	76	$40
1909	1,209.37	25,000	191	99
1910	483.75	10,000	76	41
1911	580.50	12,000	92	49
1912	967.50	20,000	164	100
1913	2,418.75	50,000	382	231
1914	2,418.75	50,000	382	211
1915	1,935.00	40,000	305	155
1916	822.37	17,000	130	86
1917	628.88	13,000	96	75
1918	1,209.37	25,000	191	191
1919	969.50	20,000	152	170
1920	725.62	15,000	99	108
	14,853.11	307,000	3,336	1,556

FORTYMILE DISTRICT.

The miners of the Fortymile district suffered losses in 1920 because of a lack of water for sluicing, as the summer was exceptionally dry. For this reason and because of the general economic conditions the output of gold was smaller than it has been for 20 years. About 22 mines, employing 30 men, were operated in the summer of 1920, and

12 mines, employing 20 men, during the previous winter. These figures show that much the larger part of this mining was done by men working alone, who obtained their gold from the relatively rich pockets of auriferous gravels. These "snipers," though their operations augment the number of mines, do not add greatly to the production of gold. The value of the recovered gold per man per year in this type of mining does not average more than a few hundred dollars, not enough to pay for a year's provisions. (See pp. 15–17.) These small operations were forced upon many of the miners because the lack of water prevented the larger operations.

Though productive mining was at a low ebb in the Fortymile district during 1920, there was some systematic prospecting of larger bodies of auriferous gravels on both Dennison and North forks. A hydraulic plant was being installed on the upper end of Jack Wade Creek. The completion of the wagon road from Eagle, part of which is now only a sled road, would do much toward stimulating the mining industry of this isolated district.

Placer gold and silver produced in the Fortymile district, 1886–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1886–1903	193,500.00	$4,000,000	30,553	$22,915
1904	14,851.12	307,000	2,345	1,360
1905	12,384.00	256,000	1,955	1,193
1906	9,868.50	204,000	1,558	1,059
1907	6,772.50	140,000	1,069	706
1908	6,772.50	140,000	1,069	567
1909	10,884.37	225,000	1,719	894
1910	9,675.00	200,000	1,528	825
1911	9,575.00	200,000	1,528	810
1912	10,303.87	213,000	1,627	1,000
1913	4,837.50	100,000	764	461
1914	2,418.75	50,000	382	211
1915	2,418.75	50,000	382	194
1916	2,418.75	50,000	382	251
1917	3,870.00	80,000	624	513
1918	3,628.12	75,000	573	573
1919	1,983.37	41,000	313	350
1920	1,935.00	40,000	348	380
	308,197.10	6,371,000	48,791	34,262

CHISANA DISTRICT.

The Chisana district is in the headwater region of Tanana River and is difficult of access. Though it lies within the Yukon basin the district receives its supplies and obtains its transportation through the Copper River basin. About 8 mines, employing 18 men, were operated in the district during the summer of 1920; there was no winter mining. Though no large deposits of valuable auriferous gravels nor rich placers were found in 1920, the gravel mined ranged from 81 cents to $12.40 per cubic yard and averaged about $2.08.

The mines were operated for an average of about 120 days. The information in hand shows that the average earnings of the miners were about $10 a day, or $1,200 for the season, so that in spite of the high cost of supplies the few miners in the district were better off than the average small operators of Alaska. (See pp. 15–17.)

Placer gold and silver produced in the Chisana district, 1913-1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1913	1,935.00	$40,000	465	$280
1914	12,093.75	250,000	2,910	1,609
1915	7,740.00	160,000	1,862	944
1916	1,935.00	40,000	465	306
1917	1,935.00	40,000	420	346
1918	725.63	15,000	160	160
1919	1,306.12	27,000	314	352
1920	967.50	20,000	137	150
	28,638.00	592,000	6,733	4,147

BONNIFIELD DISTRICT.

Small-scale placer mining was done on Moose, Eva, and Daniel creeks, in the Bonnifield district, during 1920. It is estimated that 6 mines were operated during the summer, employing about 10 men. The coal mining in the Nenana field, lying within the Bonnifield district, has already been described (p. 126).

Placer gold and silver produced in the Bonnifield district, 1903–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903-1906	1,451.25	$30,000	227	$136
1907	241.87	5,000	38	25
1908	241.87	5,000	38	20
1909	2,418.75	50,000	379	197
1910	483.75	10,000	76	41
1911	967.50	20,000	152	81
1912	967.50	20,000	152	93
1913	967.50	20,000	152	92
1914	1,451.25	30,000	227	126
1915	967.50	20,000	152	77
1916	483.75	10,000	76	50
1917	580.50	12,000	98	81
1918	580.50	12,000	91	91
1919	483.75	10,000	75	84
1920	241.87	5,000	38	41
	12,529.11	259,000	1,971	1,235

KANTISHNA DISTRICT.[31]

The mining of galena ores carrying much silver at the Quigley mine, in the Kantishna district, has greatly stimulated prospecting for both lodes and placers in the district. Mining was probably more active in the Kantishna than in any other district of the Yukon region. The production from placer mining was, however, about the same as in previous years. About 20 mines, employing about 55 men, were operated in the summer of 1920. The largest output of gold was made on Glenn Creek; the next creeks in order were Eureka, Moose, Little Moose, and Wickersham. The placers of the district are not rich, the value of the average gold recovery from them in 1920 being about $1 a cubic yard. This district, however, contains some considerable bodies of low-grade gravel; which should give profitable returns if worked on a large scale.

Placer gold and silver produced in the Kantishna district, 1903-1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1903-1906	8,465.62	$175,000	1,325	$795
1907	725.62	15,000	114	75
1908	725.62	15,000	114	60
1909	241.87	5,000	38	20
1910	483.75	10,000	76	41
1911	1,451.25	30,000	227	120
1912	1,451.25	30,000	227	140
1913	1,451.25	30,000	227	137
1914	967.50	20,000	152	84
1915	967.50	20,000	152	77
1916	1,451.25	30,000	227	149
1917	725.63	15,000	120	99
1918	1,451.25	30,000	227	227
1919	725.63	15,000	114	128
1920	1,209.37	25,000	320	349
	22,494.36	465,000	3,660	2,501

Stewart[32] has summarized the lode mining developments in the district during 1920 as follows:

Aitken property (Quigley mine).—The twenty-odd claims comprising this property, owned by Quigley & Dalton, are being worked under option by Mr. Thos. P. Aitken. The group practically covers the ridge forming the divide between Friday and Eureka creeks (known as Quigley Mountain) and extends from the low bench bordering Moose Creek to the summit of Quigley Mountain.

Work under this option has continued throughout the past two seasons, and a considerable amount of high-grade ore has been shipped to the Selby smelter, at San Francisco.

Mining and shipping costs under present conditions make shipment of ore running less than 200 ounces in silver to the ton prohibitive. The ore consists principally of silver-bearing galena and gray copper (tetrahedrite).

[31] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, 1919.

[32] Stewart, B. D., Annual report of the Territorial mine inspector to the governor of Alaska, 1920, pp. 12-14, 1921.

The mine equipment at the Aitken camp consists of a blacksmith shop, ore-assorting table and grizzly, and a combined bunkhouse and boarding house with bunks for fifteen men. Eleven men were employed at the time of visit.

Shipments have been made from two distinct ore shoots. These are practically parallel, running northeasterly and southwesterly and separated by a distance of a few hundred feet.

During the season of 1919 work was confined to the upper or southerly one of these two ore bodies. The workings consist of a shaft 100 feet in depth, from which drifts were run at the 30 and 60 foot levels below the collar. As mined, this shoot has been shown to be over 200 feet in length. A crosscut tunnel was run, at the elevation of the bottom of the shaft, having a length of approximately 300 feet, and from this a drift was run to connect with the bottom of the shaft. No work was being done on this shoot, and the workings were obstructed by ice at the time of visit, in October, 1920.

The ore body now being exploited is opened by a shaft 40 feet deep, connection with the bottom of which is made by a crosscut tunnel, known as the main tunnel, 130 feet long, and a drift on the ore shoot approximately 75 feet in length. A second crosscut 90 feet long has been driven at a distance of about 40 feet from the main tunnel and parallel to it, from which a drift has been run westerly, almost connecting with the main tunnel.

At the time of visit stoping was in progress in the vicinity of the shaft above the main level. A shaft located on the strike of the above-described ore body and about 150 feet east of the main tunnel had been started on the outcrop and was down about 20 feet, with work still proceeding in it. Very good ore was being secured from this shaft.

Galena lode.—The Galena lode prospect is described in United States Geological Survey Bulletin No. 687, pp. 105–106.

This property is now controlled by Mr. James Haney, who has established a camp on the ground and has outlined a systematic program of development, which is being put through this winter.

A sled road has been built to the workings and a season's supplies laid in at the camp.

At the time of visit (October, 1920) approximately 50 tons of high-grade ore had been taken out and sacked for shipment, and it was estimated that at least an additional 100 tons would be sacked during the winter. Surface prospecting had been carried on at numerous places with encouraging results.

During the present winter it is planned to drive a 75-foot crosscut on the ground and then sink a winze on the ore zone in order to prospect the deposit at greater depth. If conditions prove favorable, a lower tunnel is proposed. With a length of 507 feet this tunnel would give a depth of 228 feet below the present tunnel.

As at the Aitken property, the ore on the Galena prospect is steel galena and gray copper, both carrying high silver content.

Red Top lode.—The Red Top lode, owned by Joseph Quigley, lies at the foot of Quigley Mountain, on the bench a short distance south of Friday Creek near its confluence with Moose Creek, and adjoins the Aitken group on the west. Numerous well-constructed and well-planned open cuts expose the outcrop of the ore shoot over a strike length of about 300 feet. The average width of the ore body appears to be about 9 feet.

The work done reveals a very encouraging showing of galena and gray copper ore which is deserving of thorough exploration.

Apex lode.—O. M. Grant has located the Apex lode, adjoining the Galena lode on the west, and lying on the bench between the Galena lode and Moose Creek. An open cut was driven during the 1920 season.

Dalton claims.—Northwest of the Apex lode and lying southwesterly from the Red Top lode are the Star, Jumbo, and Caribou lodes, located by Joseph Dalton, who has done some open-cut work upon them.

RUBY DISTRICT.

The Ruby district has the distinction among the larger Yukon camps of having slightly increased its gold output in 1920 over that of 1919. (See subjoined table.) In this district 30 mines, employing 95 men, were operated in the summer, and 8 mines, employing 34 men, in the previous winter. The largest output of gold was obtained from 6 mines on Long Creek. Greenstone, Poorman, and Birch creeks were next in output of gold. Much the larger part of the mining was done on deep placers, and this work was confined chiefly to deposits rich in gold. Returns that were complete enough to allow the computation of the recoveries of gold were received from 14 mines, in which the value of the gold recovered per cubic yard ranged from $2.14 to $11.80 and averaged $4.85. The value of the average recovery of gold for the entire district, including all forms of mining, is estimated at $3.90 per cubic yard.

Placer gold and silver produced in the Ruby district, 1907–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1907-8	48.38	$1,000	7	$4
1909	....	....	....	....
1910	....	....	....	....
1911	....	....	....	....
1912	8,465.63	175,000	1,157	712
1913	37,974.37	785,000	5,188	3,134
1914	48,375.00	1,000,000	6,609	3,655
1915	33,862.50	700,000	4,626	2,345
1916	41,118.75	850,000	5,618	3,697
1917	42,811.88	885,000	6,073	5,046
1918	19,350.00	400,000	3,000	3,000
1919	7,981.88	165,000	1,255	1,406
1920	8,223.75	170,000	1,113	1,213
	248,212.14	5,131,000	34,646	24,212

In the summer of 1920 a galena deposit was discovered 13 miles south of Ruby, on the north side of Beaver Creek, near the mouth of Dome Creek and a mile and a half east of the wagon road from Ruby to Long. The rocks in the vicinity are quartzites and quartzitic schists, which are part of the "Paleozoic or older undifferentiated metamorphic rocks" described by Mertie and Harrington.[a] The locality was visited early in August by G. C. Martin, who reports that several deep trenches and pits and short tunnels had been dug into the hillside. Part of the exposures in these openings may be in place, but it is doubtful whether any rock that is wholly undisturbed had been revealed in them. Most of the galena occurs in narrow

[a] Mertie, J. B., jr., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 642, pp. 230-231, pl. 11, 1916.

veins and stringers in the schist. The veins seem to cut the bedding planes at a low angle. A vein about 2 feet wide was indicated by the material exposed in one cut, but there was some doubt as to its actual width. In the frozen talus on the lower slope of the hillside blocks of ore, some as much as 2 feet square, lie scattered for at least half a mile up and down the creek. These blocks may have been derived from one lode, but there are indications of the existence of several veins. The ore seen in the talus and in the prospect openings is much oxidized and iron-stained and was apparently derived from a heavy gossan.

INNOKO DISTRICT.

During the summer of 1920 there was an unusually large supply of water for sluicing in the Innoko district, but unfortunately the camp was short of supplies, for the rivers had frozen up early in the fall of 1919 and provisions had to be brought in from the Kuskokwim at a cost of 10 cents a pound for transportation. There was also some shortage of labor.

In all 21 mines, employing 50 men, were operated during the summer of 1920, and 7 mines, employing 36 men, during the previous winter. Of the total gold output (see subjoined table) about $7,000 was won from the placers of the Tolstoi region, chiefly from those of the Madison Creek basin. The largest placer-mining operations in the district were those on Ophir Creek; next in order of production were those on Spruce, Victor, and Ganes creeks. The largest gold output has come from open-cut summer mining. Returns received from six of the large open-cut workings in this district showed that the value of the gold recovery ranged from 74 cents to $1.90 and averaged $1.28 to the cubic yard. These returns are well above the minimum required for profitable dredging. The information at hand indicates that the district includes large areas of dredging ground. Separate plans are now under way to install four dredges. The two dredges for Yankee Creek were frozen in on Kuskokwim River in the fall of 1920. A project for moving the Greenstone dredge in the Iditarod district to Ganes Creek in 1920 failed on account of the early freeze-up. These three dredges may be installed before the end of 1921.

Placer gold and silver produced in the Innoko and Tolstoi districts, 1907–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1907	628.87	$13,000	67	$44
1908	3,483.00	72,000	370	196
1909	16,447.50	340,000	1,746	908
1910	15,721.87	325,000	1,669	901
1911	12,093.75	250,000	1,284	681
1912	12,093.75	250,000	1,284	681
1913	13,545.00	280,000	1,438	869
1914	9,675.00	200,000	1,027	568
1915	9,191.25	190,000	976	495
1916	10,642.50	220,000	1,130	744
1917	8,465.63	175,000	1,113	917
1918	5,805.00	120,000	606	608
1919	6,772.50	140,000	717	803
1920	4,982.62	103,000	529	577
	129,548.24	2,678,000	13,958	8,992

IDITAROD DISTRICT.

Twelve open-cut mines and two dredges were operated in the Iditarod district in the summer of 1920 and employed a total of 176 men. The dredges were operated on Otter Creek, and most of the other mining was done on Flat Creek, but some was done on Chicken, Happy, and Willow creeks. Both the dredges were operated from early in May until about the middle of November and worked on ground about 13 feet deep. Other mines were operated for an average of about 120 days. The average value of the gold recovery for all workings, including the dredges, was 90 cents a cubic yard. Returns from 7 open-cut mines were complete enough to permit computation of the gold recovery, which ranged from 56 cents to $2.40 a cubic yard and averaged $1.45. These returns came from ground ranging from 3 to 15 feet deep. These 7 open-cut mines were worked in part by the hydraulic method, in part by steam scrapers, and in part by pick and shovel.

Placer gold and silver produced in the Iditarod district, 1910–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1910	24,187.50	$500,000	4,254	$2,297
1911	120,937.50	2,500,000	21,270	11,273
1912	169,312.50	3,500,000	29,778	18,313
1913	89,977.50	1,860,000	9,551	5,769
1914	99,652.50	2,060,000	10,578	5,849
1915	99,168.75	2,050,000	10,526	5,337
1916	94,331.25	1,950,000	10,013	6,589
1917	72,562.50	1,500,000	11,050	9,105
1918	59,985.00	1,240,000	9,000	9,000
1919	35,071.88	725,000	5,300	5,937
1920	24,429.37	505,000	3,628	3,954
	889,616.25	18,390,000	124,948	83,423

It is reported that a cinnabar-bearing lode on Montana Creek, tributary to upper Iditarod River, is being developed. (See p. 24.) A galena prospect in the Kaiyuk Range, about 20 miles south of the Yukon below Louden, which was discovered several years ago, was being developed in the summer of 1920. This locality has not been visited by any member of the Geological Survey, but uncertain evidence indicates that areas in the vicinity contain schist and diabase.[34] It was reported in the summer of 1920 that a vein containing 18 inches of solid galena had been discovered, and later that 175 tons of ore was mined from the prospect in the winter of 1920–21.

MARSHALL DISTRICT.

The Marshall district, which lies in the Wade Hampton recording precinct, has been described by Harrington.[35] About 8 mines, employing 30 men, were operated in the district during the summer of 1920. Most of the gold obtained was taken from the Willow Creek placers, which are from 2 to 3 feet deep and from which the gold recovery is \$4 to \$6 a cubic yard.

Some new placer ground is said to have been developed on Stuyak Creek, which enters Yukon River from the west about 8 miles above the Russian Mission, and some on Kato Creek, which is in the immediate vicinity.

Placer gold and silver produced in the Marshall district, 1914–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1914	725.62	\$15,000	94	\$52
1915	1,209.37	25,000	156	79
1916	13,061.25	270,000	1,686	1,109
1917	20,559.37	425,000	3,300	2,719
1918	7,256.25	150,000	940	940
1919	4,837.50	100,000	624	699
1920	4,353.75	90,000	552	602
	52,003.11	1,075,000	7,352	6,200

INDIAN RIVER AND GOLD HILL DISTRICTS.

Some mining has been done in the Indian River and Gold Hill districts of the middle Yukon, but it has practically ceased. During 1920 only three mines were operated in these two districts, employing eight men in all, and the value of their total output of gold was only \$2,000.

[34] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 43–44, pl. 2, 1910.

[35] Harrington, G. L., The Anvik-Andreafski region, Alaska: U. S. Geol. Survey Bull. 683, 1918.

Placer gold and silver produced in the Indian River and Gold Hill districts, 1911–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1911	483.75	$10,000	69	$37
1912	1,185.19	24,500	170	105
1913	1,548.00	32,000	221	133
1914	1,209.37	25,000	173	96
1915	725.63	15,000	104	53
1916	483.75	10,000	69	45
1917	241.88	5,000	27	22
1918	193.50	4,000	29	29
1919	338.62	7,000	52	58
1920	96.74	2,000	2	2
	6,506.43	134,500	916	580

CHANDALAR DISTRICT.

The Chandalar district,[36] lying north of the Yukon, is one of the isolated camps in which a little placer gold has been mined for a number of years (see subjoined table) and in which a little gold-lode mining has been attempted. Up to 1919 no rich placers had been found in the district, and the mining amounted to little more than getting out a "grub stake" by a few men. In 1919 some promising deposits were discovered on Squaw and Big creeks, and these were systematically developed in 1920, yielding good returns. The principal part of the output of gold has come from these two creeks. These deposits, which include some deep ground, seem to be valuable enough to justify further prospecting. It is said that nearly 50 men are prospecting the district. The gravels mined in 1920 yielded about $5.50 to the cubic yard.

Placer gold and silver produced in the Chandalar district, 1906–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1906–1912	2,902.50	$60,000	416	$241
1913	266.06	5,500	38	23
1914	241.87	5,000	35	19
1915	241.87	5,000	35	18
1916	435.37	9,000	62	41
1917	725.63	15,000	104	86
1918	628.88	13,000	96	96
1919	453.75	10,000	79	88
1920	870.75	18,000	125	136
	5,895.93	122,500	990	748

[36] Maddren, A. G., The Koyukuk-Chandalar region: U. S. Geol. Survey Bull. 532, 1913.

KOYUKUK DISTRICT.

About 20 mines, employing 55 men, were operated in the Koyukuk district in the summer and 5 mines, employing 15 men, during the winter of 1920. The average gold recovery for all mining was about $2.50 a cubic yard. The annual gold output of the district has heretofore been chiefly maintained by the exploitation of very rich deep placers, whose gold content was from $4 to $12 a yard and averaged much more than $5. These bonanza deposits have been of no great extent, but their richness has made their exploitation very profitable. Most of them, however, are very irregularly distributed, and their discovery involves much expensive dead work. The present relatively low average gold recovery is due to the fact that mining now includes a much greater percentage of open-cut work than it did in the past. The mines are now operating on placers which, though of greater bulk than the deep bonanzas, have a much smaller gold content per cubic yard. A number of small hydraulic plants are being successfully operated in the district. Most of the gold output of the district in 1920 came from Myrtle, Nolan, Jay, and Smith creeks.

Placer gold and silver produced in the Koyukuk district, 1900–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1900-1909	106,454.02	$2,200,600	15,242	$8,993
1910	7,740.00	160,000	1,108	598
1911	6,772.50	140,000	970	514
1912	9,675.00	200,000	1,385	852
1913	19,350.00	400,000	2,770	1,673
1914	12,577.50	260,000	1,800	995
1915	13,303.12	275,000	1,902	964
1916	14,996.25	310,000	2,147	1,413
1917	12,093.75	250,000	1,700	1,401
1918	7,256.25	150,000	860	860
1919	5,321.25	110,000	760	851
1920	4,353.75	90,000	146	159
	219,893.39	4,545,600	30,790	19,273

KUSKOKWIM REGION.

The value of the placer gold output of the Kuskokwim region in 1919 was about $350,000 and in 1920 was about $305,000. These figures are only approximate, for many of the mine operators failed to report their output. About 32 placer mines, employing about 125 men, were operated in the summer of 1920, and there was no winter mining. More prospecting, both lode and placer, was done in the Kuskokwim region than in any other part of Alaska. This activity was largely stimulated by the large-scale prospecting of the Treadwell lode property in the Nixon Fork basin, first opened up in 1919.

G. C. Martin has prepared the following statement concerning mining in the McKinley district, of which McGrath is the post office and supply point:

So far as known, only two large and three small placer mines were operated in the McGrath district in 1920. The large operations are the dredge on Candle Creek and a hydraulic mine on Moore Creek, a tributary of Tacotna River. One of the small mines is on Hidden Creek and two are on Ruby Creek, all in the basin of Nixon Fork. The Kuskokwim Dredging Co. operated its dredge on Candle Creek from May 24 to October 13, except during an interruption in September on account of a broken shaft. It employed an average of 22 men and handled 74,597 cubic yards of gravel. The Moore Creek hydraulic plant is mining gravel about 14 feet in depth. The mine on Hidden Creek is exploiting a deposit 75 to 125 feet wide and about 4 feet deep. One of the mines on Ruby Creek is deep, and the other is a small open cut.

Much prospecting for gold lode veins was done in the Nixon Fork region during the summer of 1920. During the previous winter several hundred tons of ore was taken from the Crystal shaft, which was shipped during the summer. Early in the spring the property from which this shipment was made and the other neighboring claims passed into the control of the Alaska Treadwell Gold Mining Co. Actual mining thereupon ceased, but active prospecting to determine the quantity of ore available was continued throughout the year. Several shafts, 50 to 100 feet deep, and numerous trenches and open cuts were dug, buildings were erected, and a large quantity of mining supplies was shipped up Kuskokwim River. B. D. Stewart, Territorial mine inspector,[37] reports that in September, 1920, three shafts, aggregating 200 feet in depth, drifts totaling 215 feet, and crosscuts totaling 110 feet were run and that 25 men were employed. Wages were $6 a day and board. Underground exploration was continued actively during the winter of 1920–21, with the hope of determining whether the quantity of ore available is sufficient to justify the installation of facilities for shipping or treating the ore.

It is believed that about 7 mines, employing about 12 men, were operated in the Georgetown district of the middle Kuskokwim during the summer of 1920. Reports of production have been received from Donlon and New York creeks, in this district, and of drilling in prospective dredging ground on Holitna River.

About 16 mines, employing 60 men, were operated in the Aniak district during the summer of 1920. The largest gold output was made on Canyon Creek, but gold was mined also on Bear, Crooked, Mary, George, and Marvel creeks and on George River. It is reported that hydraulic plants are being installed on Spruce Creek and Tiny Gulch, both tributary to Bear Creek. Some developments have been continued on a copper and gold bearing lode in the Russian Mountains 12 miles north of Kolmakof, on the Kuskokwim.[38] It is reported that a 50-foot shaft has been sunk on the lode.

The Parks quicksilver mine, on the lower Kuskokwim, was operated in a small way during 1920. E. W. Parks reports the discovery of a stibnite-realgar lode in the vicinity of Barometer Mountain. This mountain lies almost due south of the Parks mine and 5 miles

[37] Op. cit., p. 18.
[38] Maddren, A. G., Gold placers of the lower Kuskokwim: U. S. Geol. Survey Bull. 622, pp. 304–305, 1915.

from the Kuskokwim. Specimens said to have come from this deposit contain stibnite and realgar. The specimens received indicate that the country rocks in which the deposits occur are Mesozoic sandstones and shales, probably of Upper Cretaceous age, and that the geologic relations are probably similar to those of the Parks cinnabar deposit, which have been described by Smith,[39] but no cinnabar was found in the ore. Smith's geologic map [40] shows that the upper part of Barometer Mountain is made up of granite, which is intruded into Mesozoic sediments. This deposit is said to have been opened up by a 100-foot adit.

Mining in the Goodnews Bay district during 1920 was confined to Watermuse, Bear, and Cow Cow creeks. One placer mine was operated on each of these creeks, and a total of 12 men were employed.

SEWARD PENINSULA.[41]

GENERAL CONDITIONS.

The value of the total mineral output of Seward Peninsula in 1920 was $1,331,017, of which $1,300,000 is the value of the placer gold and the rest that of silver, platinum, tin, and coal. In 1919 the total value of the mineral output was $1,423,449, and that of placer gold was $1,360,000. A little platinum was recovered from the gold placers of the Koyuk and Fairhaven districts. (See p. 23.) Tin ore was mined in the York district on a reduced scale as compared with previous years, only one dredge and one small open-cut mine being operated on tin placers. (See p. 22.) A small output of coal was made from a lignite mine in the Fairhaven district. In the aggregate, there was considerable prospecting of lode deposits during the year. An experimental shipment of garnet sand to be used as abrasive was made from Nome in the summer of 1920. (See p. 33.)

The present insufficient steamship service to Nome is a great handicap to all forms of mining. This and the increased cost of transportation and supplies have prevented the development of new mining enterprises. No new mineral deposits were discovered in Seward Peninsula during the year.

PLACER MINING.

About 112 mines, employing 540 men, were operated on Seward Peninsula in the summer of 1920, and 8 mines, employing 60 men, during the previous winter. In 1919 there were about 103 summer mines, employing 555 men, and 10 winter mines, employing about 60 men. This increase in the number of mines does not indicate a

[39] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 139-148, 1917.

[40] Op. cit., pl. 5.

[41] A part of the information here presented is taken from a longer report by S. H. Cathcart, which, because of a shortage of printing funds it has seemed best not to publish in complete form.

growth of the mining industry, because nearly all were very small operations, and many were worked solely because the unusual abundance of water for sluicing gave opportunity for exploiting placers which under more normal conditions could not be worked. The small scale of the operations is indicated by the fact that returns from 19 of the mines showed a total value of gold output of only $10,870, and a total personnel of only 30 men. Moreover, many of these mines were worked for only a part of the mining season. It is estimated that 1,790,000 cubic yards of gold-bearing gravel were mined and sluiced on Seward Peninsula in 1920. The value of the average gold content of this gravel was about 73 cents to the cubic yard. In 1919 about 2,165,000 cubic yards of gravel was mined and the average gold content was 63 cents to the cubic yard. The decrease in 1920 is due to a decrease in the number of dredges operated.

The sources of the placer-gold output of Seward Peninsula, both by districts and by methods of mining, is shown in the following tables. The figures presented are in part based on estimates, but their possible error is believed to be not over 8 per cent.

Placer gold produced in Seward Peninsula in 1920, by districts.

District.	Value of gold output.	Summer.		Winter.	
		Mines.	Miners.	Mines.	Miners.
Nome	$540,000	30	216	5	20
Solomon and Casadepaga	50,000	8	32		
Koyuk	160,000	14	55	3	33
Council	360,000	17	70		
Kougarok	55,000	14	52		
Fairhaven	135,000	23	90	2	8
Port Clarence, etc.		6	25		
	1,300,000	112	540	10	61

Placer gold produced in Seward Peninsula in 1920, by methods of mining.

Method.	Number of mines.	Number of miners.	Value of gold.
Dredging	17	145	$475,000
Hydraulic (includes all operations where any water is used to move gravel to sluice boxes)	28	200	500,000
Underground	14	65	155,000
Open-cut (other than hydraulic)	53	130	170,000
	112	540	1,300,000

In the Inmachuk region, as in other parts of the peninsula, gravels occur underneath basaltic volcanic flows.[43] During the last two years some of these buried gravels have been prospected with reported favorable results. In 1920 a considerable body of gravel on Candle Creek, in the Fairhaven district, was thawed by the cold-water method, with a view of dredging it in 1921. Some systematic investigations of

[43] Moffit, F. H., The Fairhaven gold-placer district, Alaska: U. S. Geol. Survey Bull. 247, pp. 31-35, 1905.

placer gravel were made in different districts of the peninsula during the summer of 1920, but on the whole not many projects looking to future large-scale operations were under way.

Dredging.—In 1920 17 gold dredges operating on the peninsula produced $475,000 worth of gold; in 1919 24 dredges produced $450,000 worth. In 1920 the dredges mined about 930,000 cubic yards of gravel containing about 51 cents worth of gold to the cubic yard; in 1919 the dredges mined only 865,000 cubic yards of gravel containing gold worth 52 cents to the yard. This greater efficiency of the dredges in 1920 lies in the fact that many of the small and comparatively inefficient dredges that contributed to the total yardage mined in 1919 were not operated in 1920 because of greater costs. Though the season of 1920 was not particularly favorable for dredging because the seasonal frost stayed in the ground rather far into the summer, the average length of operation was nearly 70 days in 1920, as compared with 50 days in 1919. The low average of 1919 was due entirely to the inefficiency of the small dredges, some of which were operated for less than 30 days. The longest operating season reported for any one dredge in 1920 was 96 days, and the longest in 1919 was 110 days.

Gold dredges operated on Seward Peninsula in 1920.

Nome district:
- Dexter Dredging Co., Dexter Creek.
- Center Creek Dredging Co., Center Creek.
- Dry Creek Dredging Co., Dry Creek.
- Arctic Creek Dredging Co., Arctic Creek.
- Alaska Mines Corporation, Flat Creek.
- Julian Dredge, Osburn Creek.

Solomon district:
- Esquimo Dredging Co., Solomon River.
- Shovel Creek Gold Dredging Co., Shovel Creek.
- Burness-Iverson-Johnson Dredge, Big Hurrah Creek.

Council district:
- Northern Light Mining Co., Ophir Creek.
- Wild Goose Mining & Trading Co., Ophir Creek.
- Crooked Creek Dredging Co., Crooked Creek.
- Flume Dredge Co., Melsing Creek.
- Flume Dredge Co., Basin Creek.

Kougarok district:
- Bering Dredging Co., Taylor Creek.
- Kelliher Dredging Co., Kougarok River.

Port Clarence district:
- Budd Creek Dredging Co., Budd Creek.

Deep mining.—Of the 14 mines working deep placers covered by a heavy overburden and carrying little or no gold that were operated in 1920 there were five each in the Nome and Koyuk districts, three in the Fairhaven, and one in the Kougarok. The deep mines of the Koyuk district produced about $86,000 and those of the Nome district about

$40,000 worth of gold. Of the total number of deep mines, seven were operated for a part of both the winter and the summer, one during the winter only and six during the summer only. The returns from 12 of these mines are sufficiently complete to permit the following analysis. These mines were operated from 30 to 307 days and an average of 146 days. They averaged nearly six employees per mine and hoisted and sluiced about 39,950 cubic yards of gravel, the value of whose gold content ranged from $2.86 to $12.62 a cubic yard. The richer of the deposits were those exploited by small miners, who were evidently working on rich pockets of placers. The average gold tenor for all the mines was $3.87 a cubic yard. An average of 3.8 cubic yards of gravel was mined per man per day, this average including all men employed both on the surface and underground.

Hydraulic and other open-cut mines.—Many of the operations classed as hydraulic were those in which only a part of the work of moving the granite to the sluice box is done by water under head. Water is not abundant enough nor are the grades steep enough in most of Seward Peninsula to permit ordinary hydraulic mining. Six hydraulic elevators were operated in 1920. The abundant rainfall during 1920, except in the Fairhaven district, favored hydraulic mining. The value of the gold recovery from the open-cut mines ranged from 45 cents to $2.40 to the cubic yard. Seventeen large open-cut mines, most of which did much hydraulic work, showed an average gold recovery of 70 cents to the cubic yard.

Gold and silver produced on Seward Peninsula, 1897–1920.

Year.	Gold.		Silver.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Value.
1897	725.63	$15,000	87	$52
1898	3,628.12	75,000	435	256
1899	135,450.00	2,800,000	16,254	9,752
1900	229,781.25	4,750,000	27,574	17,097
1901	199,822.61	4,130,700	24,579	14,747
1902	220,677.07	4,561,800	26,481	14,035
1903	215,994.38	4,465,000	24,171	13,052
1904	201,462.52	4,164,600	24,175	14,021
1905	232,200.00	4,800,000	27,864	16,997
1906	352,812.50	7,500,000	43,537	29,606
1907	338,625.00	7,000,000	25,497	16,828
1908	247,680.00	5,120,000	20,577	10,905
1909	207,077.50	4,260,000	20,871	10,853
1910	169,312.50	3,500,000	20,317	10,971
1911	149,962.50	3,100,000	17,996	9,718
1912	145,125.00	3,000,000	17,415	10,710
1913	120,937.50	2,500,000	12,094	7,305
1914	130,612.50	2,700,000	15,673	8,667
1915	140,287.50	2,900,000	17,510	8,878
1916	142,706.25	2,950,000	14,271	9,391
1917	125,775.00	2,600,000	13,770	11,346
1918	53,599.50	1,108,000	6,022	6,022
1919	65,790.00	1,360,000	6,940	7,773
1920	62,887.49	1,300,000	6,813	7,426
	3,892,932.32	80,660,100	430,928	266,407

LODE MINING AND PROSPECTING.

Little work was done on the lodes of Seward Peninsula in 1920. Explorations that were in progress at several localities have been discontinued for the present. The necessity of resuming annual assessment work occasioned some prospecting, but it was very desultory. About 50 men were engaged in lode prospecting for a part of the year.

The only production from lode mining in 1920 was that made by the gold-quartz property of Megan, Somerville & Megan, at Bluff. A dump mined during the winter was milled in the spring. Mr. Tom Ward worked three men for part of the summer on his copper property near Kougarok Mountain. He planned to sink on and crosscut the ledge in the winter of 1920–21. During the winter of 1920 a force of about 20 men was employed in exploring the tin lode on Cassiterite Creek. A 250-foot inclined shaft was sunk on the dike from a station on the lower tunnel. Work was discontinued in May.

Twenty men were employed during the winter and eight during the summer in prospecting the lead-silver property on Kugruk River. The developments on the property now consist of a 140-foot shaft and of 250 feet of drift on the 40-foot and 150 feet of drift on the 140-foot levels. The showing is considered favorable by the owners. Work was discontinued in September.

COMMERCIAL CONDITIONS.

There was some shortage of labor on Seward Peninsula during the summer of 1920, but it was not serious. Most of the dredging companies brought their crews with them, so that the dredges could not be operated until after navigation opened, about the end of June. The summer wage for common labor was $6 and board for an 8-hour day, but many of the larger companies insisted on a longer day. The winter wage in the Koyuk district was $5 and board for an 8-hour day. The average dredge wage for engineers and winchmen was $9 and board, the men working in 12-hour shifts. Many of the men were brought in and taken out during the summer, and probably most of them were paid for the entire season, including time spent in travel.

Board at Nome cost $2.50 to $3.50 a day, and it probably cost the mining companies at least $2 a day to feed their men. The cost of provisions at Nome in the summer of 1919 is indicated by the following retail prices per pound: Bacon, 75 cents; butter, 85 cents; sugar, 30 cents; flour, 10 cents; beans, 20 cents; potatoes, 15 cents; rice, 20 cents; eggs, 85 cents a dozen.

The price of coal per ton at Nome in 1920 was $39 in summer and $45 in winter. Fuel oil sold at $6 a barrel, gasoline at 60 cents a

gallon, and distillate at 49 cents a gallon. At Dime Creek, in the Koyuk district, where there is timber, the price of wood was $16 a cord.

In 1920 the first of the summer fleet arrived at Nome on June 13, but shore ice prevented landing of freight until June 23. Storms began July 4, and tied up all coastwise shipping for three weeks and seriously interfered with the unloading of the vessels. The last of the freighters did not leave Nome until August 4, so that their return trips were delayed until September, a delay that seriously hampered mining. Three dredges did not receive their supplies and provisions until September and lost practically the whole season.

The freight rates vary, of course, with the classification, but the ordinary freight rate from Seattle to Nome and Anchorage was about $19 a ton l. c. l.[43] To this rate must be added the lighterage charge paid on all freight for transportation from shipside to beach. In 1920 the lighterage at Nome for ordinary freight was $10 a ton.[44] It is to be hoped that the completion of the jetty at the mouth of Snake River, which is now being built by the Government and which will give a safe harbor for barges and small craft, will lead to a reduction of the lighterage charges.

Even after the freight is landed on the beach at Nome or other settlement the miner may still have to meet the heavier cost of overland transportation. For the mines that are reached by the good local roads leading out from Nome the cost of transportation is only about $3 a ton. On the other hand, the price charged for hauling freight from Nome to Boulder Creek (10 miles) was $50, to Goldbottom Creek (16 miles) $66, and to Manila Creek (20 miles) $94 a ton. In the Koyuk district freight rates from steamer landing on Norton Sound to Dime Creek, a distance of 20 miles, are $50 a ton in summer and $30 a ton in winter. The above rates show that the placer miner, unless he is on the good system tributary to Nome, must pay from $2.50 to $5 a ton per mile for the land transportation of his freight, which has already cost him $30 to $50 landed on the beach. This is one of the best arguments for more road construction in the Alaska placer camps.

All this goes to show that cost of transportation is the heaviest drain on mining. The total cost of delivering freight to the camps on Seward Peninsula[45] is estimated as follows: Ocean freight,

[43] Examples of freight rates are coal (c.l.), $13.65; explosives, $35.50; automobiles, $64.50 to $109 per ton. The freight rate to Golovin in 1920 was $21; Teller, $23.50; Lost River, $26.25; York and Kotzbue settlement, $29.

[44] Examples of lighterage on different classes of freight at Nome are as follows: Coal, $8; machinery, $10; explosives, $14 a ton. Lighterage at Bonanza, $15; at Teller, $7.50; and at Kotzebue, $8. The following coastwise freight rates were in effect in 1920: Nome to Dime Landing, $20; Nome to Solomon, $12; Teller to York, $10; Teller to Kotzebue, $40.

[45] According to report of R. W. J. Reed, customs collector of the port of Nome, dated October 21, 1920, the following freight was landed in 1920: General merchandise, 7,599 tons; coal (domestic), 2,511 tons; (foreign), 315 tons; lumber, 734,574 feet b. m.; live stock, 16 head.

Seattle to Nome, $200,000; lighterage at Nome, $106,000; local distribution, $170,000. These figures include freight landed by coastwise, river, and land transportation and are based on the costs considered on preceding pages and on estimates of percentages of total freight delivered to each district. The figures are only approximate, but they are underestimates rather than overestimates. They amount to $476,000, equal to about 29 per cent of the value of the total gold output of the peninsula in 1920. This cost of transportation has to be met by the mining industry, for except for the production of a little salt fish and reindeer meat, Seward Peninsula has no other industries.

KOBUK REGION.

As a result of the high cost of transportation and supplies mining has almost ceased in the Kobuk region. Three small mines, however, were operated on Dahl Creek, and four on Kleary Creek, and in all 10 men were employed for a short time in winter and summer. The value of the total gold output of these mines was about $8,000. Plans have been made to install a hydraulic plant on Dahl Creek.

The coastal port for this district is Kotzebue, to which the freight rates from Seattle, including lighterage, are about $40. From Kotzebue the freight is taken by boat up the Kobuk to Shungnak, the local supply point of the Dahl Creek region. The cost of this river transportation is $40 a ton. Therefore, the miner in the Dahl Creek region pays freight amounting to at least $80 a ton on all his supplies.

ADMINISTRATIVE REPORT.

By Alfred H. Brooks.

During 1920 eight parties were engaged in surveys and investigations in Alaska. These parties included 7 geologists, 2 topographers, 1 hydraulic engineer, and 14 packers, cooks, and other auxiliaries. Five parties were engaged in geologic work, one in topographic survey, one in investigations of water powers in southeastern Alaska in cooperation with the Forest Service, and one was a combined geologic and topographic party.

The funds available for field and office work for the season of 1920 included an appropriation of $75,000 and an unexpended balance of $10,400 from the appropriation for the previous year. The subjoined tables show the allotments of these funds geographically by types of work and by salaries and field expenses. A balance of $13,800 will be used for the field work of 1921. In these tables the money devoted purely to office work has not been allocated to the several projects, as in previous administrative reports. These overhead charges, including administration, amount to about 23 per cent of the total and may be properly allocated to the projects at this ratio.

Approximate general distribution of appropriations for investigations in Alaska, field season of 1920.

	1919-20	1920-21
General geologic investigation		$2,700
Southeastern Alaska		9,240
Prince William Sound		1,400
Cook Inlet	$3,500	8,910
Southwestern Alaska		1,000
Susitna region	3,750	5,610
Yukon basin	1,600	4,420
Kuskokwin basin	300	5,380
Seward Peninsula	1,150	3,200
Administrative		4,250
Collection of mineral statistics		1,900
Miscellaneous expenses, including clerical work, office supplies, etc	100	13,190
Balance to be allotted to field work, 1921		13,800
	10,400	75,000

Approximate allotments to different kinds of surveys and investigations, field season of 1920.

	1919-20	1920-21
Reconnaissance geologic surveys	$3,400	$13,820
Special geologic investigations	1,150	13,825
Topographic reconnaissance surveys	5,750	9,870
Investigation of water resources		4,345
Administrative		4,250
Collection of mineral statistics		1,900
Miscellaneous expenses, including clerical work, office supplies, map compilation, etc.	100	13,190
To be allotted to field work, 1921		13,800
	10,400	75,000

Allotments for salaries and field expenses, field season, 1920.

	1919-20	1920-21
Scientific salaries		$29,395
Field expenses	$10,300	16,115
Clerical salaries and miscellaneous expenses	100	15,690
To be allotted to field work		13,800
	10,400	75,000

The following table shows the progress of investigations in Alaska and the annual grants of funds since systematic surveys were begun, in 1898.[1] It should be noted that a varying amount is spent each year on special investigations that yield results which can not be expressed in terms of area. In 1917, when the war broke out, nearly all the Alaska funds were allotted to the investigation of minerals such as platinum, sulphur, antimony, etc., which were then of special importance, and few areal surveys were made. Since then the reduction of the annual appropriation and the increased cost of all field work has not permitted extensive geologic and topographic surveys. Little progress has therefore been made in extending the topographic and geologic surveys which are essential to obtain an adequate knowledge of the mineral resources of the Territory.

[1] The Geological Survey made some investigations of the gold and coal deposits of the Pacific seaboard region in 1895 and of the Yukon region in 1896.

Progress of surveys in Alaska, 1898–1920.

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[a]					Investigations of water resources.	
		Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000).	Detailed (scale 1:62,500).	Exploratory (scale 1:625,000 or 1:1,000,000).	Reconnaissance (scale 1:250,000; 200-foot contours).	Detailed (scale 1:62,500; 25, 50, or 100 foot contours).	Lines of levels.	Bench marks set.	Gaging stations maintained part of year.	Stream-volume measurements.
		Sq. m.	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Sq. m.*	*Miles*			
1898	$46,189	9,500	......	......	12,840	2,070	......	......	...	......	......
1899	25,000	6,000	......	......	8,690	......	......	......	...	......	......
1900	60,000	3,300	6,700	......	630	11,150	......	......	...	......	......
1901	60,000	6,200	5,800	......	10,200	5,450	......	......	...	......	......
1902	60,000	6,950	10,050	......	8,330	11,970	96	......	...	......	......
1903	60,000	5,000	8,000	96	......	15,000	......	......	...	......	......
1904	60,000	4,050	3,500	......	800	6,480	480	86	19	......	......
1905	80,000	4,000	4,100	536	......	4,880	787	202	28	......	......
1906	80,000	5,000	4,000	421	......	13,500	40	......	...	14	286
1907	80,000	2,600	1,400	442	......	6,120	501	95	16	48	457
1908	80,000	2,000	2,850	604	......	3,980	427	76	9	53	556
1909	90,000	6,100	5,500	450	6,190	5,170	444	......	...	81	703
1910	90,000	......	8,635	321	......	13,815	36	......	...	69	429
1911	100,000	8,000	10,550	496	......	14,460	246	......	...	68	309
1912	90,000	......	2,000	525	......	......	298	......	...	69	381
1913	100,000	3,500	2,950	180	3,400	2,535	287	......	...	......	......
1914	100,000	1,000	7,700	325	600	10,300	10	......	...	......	......
1915	100,000	......	10,700	200	......	10,400	12	3	2	9	......
1916	100,000	......	5,100	636	......	9,700	67	......	...	20	......
1917	100,000	......	1,750	275	......	1,050	......	......	...	19	......
1918	77,000	......	3,500	......	......	1,200	......	......	...	......	......
1919	75,000	......	2,700	......	......	2,300	......	......	...	19	......
1920	75,000	......	1,480	......	......	770	......	......	...	19	......
1921	......	......	......	......	......	......	......	......	...	......	......
1922	......	......	......	......	......	......	......	......	...	......	......
	1,788,189	73,200	108,965	5,507	51,680	152,300	3,731	462	74	......	......
Percentage of total area of Alaska	......	12.48	18.58	0.94	8.81	25.97	0.64	......	...	......	......

[a] The Coast and Geodetic and International Boundary surveys have also made topographic surveys in Alaska. The areas covered by these surveys are of course not included in these totals.

The writer was engaged in office work until July 4, when he accompanied Hon. John Barton Payne, Secretary of the Interior, and Hon. Josephus Daniels, Secretary of the Navy, to Alaska. In the course of this journey a part of the Matanuska coal field and the Government railroad were examined. Through the courtesy of Admiral Hugh Rodman the writer was later enabled to visit Cold Bay, on the Alaska Peninsula. This part of the journey was made on the United States destroyer *McCullough*, commanded by Capt. H. W. Sears. Through the courtesy of Captain Sears the writer was transported to Juneau and later went to Cordova by passenger steamer. A visit was then made to the Bering River coal field and the Katalla oil field. The time from August 24 to September 13 was spent in examining the copper and gold lodes of Prince William Sound and in studying the local geology. A part of this work was done in company with O. C. Ralston, metallurgist of the United States Bureau of Mines.

Later, again in company with Mr. Ralston, the writer devoted 10 days to an examination of some of the copper deposits of the Ketchikan district. Returning, the writer reached Washington October 4. Of the nine months devoted to office work during the year 1920, 51 days were devoted to progress report, 8 days to preparation of annual press bulletin, 11 days to field plans, 7 days to reading manuscript, 22 days to military geology, 9 days to geologic studies, and 43 days to preparation of a report on conditions in Alaska, for the Secretary of the Interior.[3]

R. H. Sargent was on furlough for about three-fourths of the year. While on duty he was occupied chiefly in the administration of the Alaska topographic surveys and map compilation.

S. R. Capps was on furlough until February 21, 1921. While on duty he was engaged chiefly in continuing his report on the geology and mineral resources of the region tributary to the railroad.

G. L. Harrington was on furlough all but about one week in the year and while on duty devoted his time chiefly to the report on the Ruby-Iditarod district.

J. B. Mertie, jr., was on furlough until March 31, 1921, and gave the rest of the fiscal year to continuation of the report on the Ruby-Iditarod district.

C. P. McKinley devoted about two months to the compilation of a topographic map of the Katmai region from photographs furnished by the National Geographic Society.

Miss Lucy M. Graves, chief clerk, has continued to carry much of the burden of the administration of the Alaska division and has acted as chief during the absence of the geologist in charge and of the senior geologist, G. C. Martin. The details of collecting the statistics of the mineral production of Alaska have been in the hands of T. R. Burch.

G. H. Canfield continued water-power investigations in southeastern Alaska up to April 1, when the work was suspended on account of lack of funds. A record of five years of stream flow has now been obtained for about 19 of the best of the water-power sites in southeastern Alaska. In view of the demands for other investigations in Alaska the continuation of the stream gaging does not appear to be justified under the present reduced appropriation. This work could not have been done without the cordial cooperation of the Forest Service, which has rendered much valuable assistance in providing local transportation, office space, and gage readers. The great importance of this water-power investigation, both to the pulp-wood and mining industry, is generally recognized, and it is hoped that funds will be available for its continuation at an early date.

[3] Report of Alaska Advisory Committee, Alfred H. Brooks, chairman: Appendix H of Report of the governor of Alaska to the Secretary of the Interior, pp. 103-114, Washington, 1921.

Lewis G. Westgate completed the geologic reconnaissance survey of the Portland Canal region of the Ketchikan district between July 19 and September 24. A summary report of his results is given in another part of this volume.

F. H. Moffit, with Herbert Insley as geologic assistant and C. P. McKinley as topographer, made a geologic and topographic reconnaisance survey covering 380 square miles in the Tuxedni Bay region of Cook Inlet between June 10 and September 10. It was originally planned to extend this survey southward to include the Iliamna Bay oil field, but this extension proved impossible on account of the almost unprecedented rainfall of the summer, which both retarded the field work and swelled the rivers and swamps so much as to make a part of the region impassable for a pack train. Mr. Moffit's report is contained in another part of this report.

J. R. Eakin made topographic reconnaissance surveys of an area of 390 square miles on the southern slope of the Alaska Range, in the headwater region of the Susitna basin. The field work, which was carried on from June 27 to August 28, was greatly retarded by rainy weather, which made it impossible to carry the survey across the range as had been planned.

Philip S. Smith devoted the time from July 17 to September 22 to a continuation and revision of the geologic reconnnaissance mapping of the Salcha-Goodpaster region. His survey, which included the investigation of mineral resources, covered a total area of 1,200 square miles, of which about 500 had been previously unmapped.

G. C. Martin continued the study of the geology and mineral resources of the Ruby, Iditarod, and Innoko districts. He also made a special investigation of the auriferous lodes of the Nixon Fork basin of the Mount McKinley district, in the upper Kuskokwim basin. The results of this work are presented in another part of this volume. The field work was carried on from July 1 to August 29.

S. H. Cathcart devoted from July 3 to September 19 to a geologic study of some of the mineral deposits of Seward Peninsula. This study is a part of a project for an intensive investigation of the mineral bearing lodes of the peninsula, which unfortunately, because of lack of funds, could not be continued in 1921. A statement of Mr. Cathcart's results is given in another part of this volume.

During 1920 the Survey issued two bulletins relating to Alaska—Bulletin 682, The marble resources of southeastern Alaska, by E. F. Burchard, and Bulletin 712, Mineral resources of Alaska, 1918, by G. C. Martin and others. A report on the mining industry of Alaska for 1920, with estimates of mineral output, was issued on January 1, 1921. On December 31, 1920, there were in press Bulletin 719, "Preliminary report on petroleum in Alaska," by G. C. Martin

(issued February, 1921); Bulletin 714, Mineral resources of Alaska, by Alfred H. Brooks and others (separate chapters issued between February and April, 1921). Two reports, including topographic maps ("The geology of the York tin deposits, Alaska," by Edward Steidtmann and S. H. Cathcart, and "The Kotsina-Kuskulana district, Alaska," by F. H. Moffit and J. B. Mertie, jr.), were transmitted in 1920 but have not yet been sent forward for printing, owing to shortage of funds for publication. As this shortage makes it impossible to foresee when reports and maps can be published, it does not seem desirable to list some 10 manuscripts and 7 topographic maps that are in various stages of preparation.

WATER-POWER INVESTIGATIONS IN SOUTHEASTERN ALASKA.

By George H. Canfield.

INTRODUCTION.

Systematic investigation of the water resources of Alaska was begun by the United States Geological Survey in 1906 and has been carried on in different parts of the Territory to the present time. This investigation was undertaken in response to the need for definite information in regard to water available for many uses, among which the most important are hydraulicking, dredging, and supplying power for mines, canneries, and sawmills.

The investigation of the water resources of southeastern Alaska was begun by the Geological Survey in cooperation with the Forest Service in 1915 and was designed to determine both the location and the possibilities of water-power sites. The results of previous years' work have already been published. A table showing water-power possibilities in southeastern Alaska is given on page 184, Bulletin 714–B.

The Geological Survey maintained a number of gaging stations in southeastern Alaska throughout the year, and other stations were installed in cooperation with individuals and corporations. The records obtained at these stations are contained in this paper. Acknowledgment is made to those who have assisted in this work, particularly to Mr. W. G. Weigle and Mr. Charles H. Flory, supervisors of the Forest Service at Ketchikan, and to Mr. Philip H. Dater, district engineer at Portland, Oreg.

The following list shows the stations which have been maintained in southeastern Alaska and the date of establishment. A dash after the date indicates that the station was in operation after December 31, 1920. The location of the stations is shown on Plate I (p. 76).

1. Myrtle Creek at Niblack, Prince of Wales Island, 1917—
2. Karta River at Karta Bay, Prince of Wales Island, 1915—
3. Ketchikan Creek at Ketchikan 1909–1912; 1915–1919.
4. Beaver Falls Creek at George Inlet, Revillagigedo Island, 1917—
5. Mahoney Creek at George Inlet, Revillagigedo Island, 1920—
6. Fish Creek near Sea Level, Revillagigedo Island, 1915—
7. Swan Lake outlet at Carroll Inlet, Revillagigedo Island, 1916—

8. Orchard Lake outlet at Shrimp Bay, Revillagigedo Island, 1915—
9. Shelockum Lake outlet at Bailey Bay, 1915—
10. Mill Creek on mainland near Wrangell, 1915–1917.
11. Cascade Creek at Thomas Bay, near Petersburg, 1917—
12. Green Lake outlet at Silver Bay, near Sitka, 1915—
13. Baranof Lake outlet at Baranof, Baranof Island, 1915—
14. Falls Creek at Nickel, near Chichagof, 1918–1920.
15. Porcupine Creek near Nickel, 1918–1920.
16. Sweetheart Falls Creek near Snettisham, 1915—
17. Crater Lake outlet at Speel River, Port Snettisham, 1913—
18. Long Lake outlet at Port Snettisham, 1913–1915.
19. Long River below Second Lake, at Port Snettisham, 1915—
20. Speel River at Port Snettisham, 1916–1918.
21. Grindstone Creek at Taku Inlet, 1916—
22. Carlson Creek at Sunny Cove, Taku Inlet, 1916—
23. Sheep Creek near Thane, 1916—
24. Gold Creek at Juneau, 1916—
25. Sherman Creek at Kensington mine, 1914–1916.

STATION RECORDS.

MYRTLE CREEK AT NIBLACK, PRINCE OF WALES ISLAND.

LOCATION.—Halfway between beach and Myrtle Lake outlet, which is one-third mile from tidewater, 1 mile from Niblack, in north arm of Moira Sound, Prince of Wales Island, and 35 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—July 30, 1917, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on right bank; reached by a trail which leaves beach near the mouth of the creek.

DISCHARGE MEASUREMENTS.—At medium and high stages made from a cable across creek at outlet of lake; at low stages made by wading.

CHANNEL AND CONTROL.—The gage is in a pool 10 feet upstream from a contracted portion of the channel, at a rocky riffle that forms a well-defined and permanent control. At the cable section the bed is smooth, the water deep, and the current uniform and sluggish.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 2.85 feet, at 1 a. m. August 6 (discharge, 169 second-feet); minimum stage, 0.95 foot, at 4 p. m. July 29 (discharge, 24 second-feet).

1917–1920: Maximum stage recorded, 4.4 feet at 5 p. m. November 18, 1917 (discharge from extension of rating curve, 387 second-feet); minimum stage, 0.95 foot, at 4 p. m. July 29, 1920 (discharge, 24 second-feet).

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 25 and 220 second-feet. Operation of water-stage recorder satisfactory, except for periods indicated in footnote to daily discharge table. Daily discharge ascertained by applying to rating table mean gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Records excellent, except for periods of break in record, for which they are fair.

Myrtle Lake, the outlet of which is 800 feet from Niblack Anchorage, is 95 feet above high tide and covers 122 acres. Niblack Lake, the outlet of which is 5,700 feet from Niblack Anchorage, is 450 feet above high tide and covers 383 acres. Mary Lake,

unsurveyed, is about 600 feet above sea level and is a mile long and one-fourth to one-half mile wide. The large lake area in this small drainage basin is the cause of the well-maintained flow during the winter and periods of little rainfall.

A tunnel about 200 feet long through the low ridge separating the outlet of Myrtle Lake from the Niblack Anchorage was practically completed in 1920 by the G. M. Wakefield Mineral Lands Co. At the lake end, the upper 2 feet only of the tunnel section was broken through, because the bottom of the tunnel is at about the same elevation as Myrtle Lake.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Myrtle Creek at Niblack, for 1920.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1			34	44	46	43	31	67	83	157	76
2			32	42	46	40	43	64	95	175	70
3			32	41	46	38	46	56	93	157	88
4			32	40	46	36	102	53	90	140	100
5			32	47	46	35	157	50	88	121	118
6			32	53	46	34	157	46	79	111	140
7			31	54	44	33	100	52	72	103	134
8			31	54	44	31	73	82	67	96	114
9			30	52	46	31	58	67	86	89	99
10			30	48	46	30	54	56	100	84	92
11		50	54	46	44	29	102	65	86	77	86
12		50	71	46	42	29	109	70	80	73	84
13	53	47	57	45	40	28	91	62	105	68	88
14	50		48	42	40	27	77	56	95	63	89
15	48		41	50	42	27	68	71	86	60	80
16	48		37	54	40	27	64	71	79	60	73
17	60		37	55	40	26	59	64	73	62	89
18	80		47	54	42	26	56	57	68	61	92
19	60	34	44	50	40	25	52	54	67	63	81
20	52	34	40	47	40	25	50	68	94	65	75
21	48	33	37	44	40	25	48	80	89	73	70
22	46	33	36	44	42	25	47	98	92	71	67
23		32	35	44	43	25	46	83	106	73	63
24		32	35	43	44	25	44	70	114	84	58
25		31	42	50	44	25	41	63	104	111	56
26		31	60	61	47	25	52	61	92	101	63
27		32	60	56	46	25	61	64	96	96	184
28		37	55	51	47	24	55	106	87	98	124
29		40	50	48	48	24	50	92	78	89	99
30		40	46	48	45	24	46	77	83	81	91
31		36		46		25	56		114		103

NOTE.—Water-stage recorder not operating; discharge estimated from maximum and minimum stages indicated by recorder and comparison with climatic data for Ketchikan and hydrographs for Fish Creek and Karta River: Jan. 1-31, 100 second-feet; Feb. 1-12, 85 second-feet; Feb. 17-19, daily discharge; Feb. 23-29, 40 second-feet; Mar. 1-10, 35 second-feet; Mar. 14-18, 40 second-feet; Apr. 19 and 20, as shown in table.

Monthly discharge of Myrtle Creek at Niblack, for 1920.

Month.	Discharge in second-feet. Maximum.	Discharge in second-feet. Minimum.	Discharge in second-feet. Mean.	Run-off in acre-feet.
January			100	6,150
February			63.6	3,660
March			36.8	2,260
April	60	30	41.6	2,480
May	61	40	48.4	2,980
June	48	40	43.7	2,600
July	43	24	28.8	1,770
August	157	31	67.6	4,160
September	106	46	67.5	4,020
October	114	67	88.4	5,430
November	175	60	92.1	5,480
December	140	56	90.2	5,550
The year		24	64.1	46,500

KARTA RIVER AT KARTA BAY, PRINCE OF WALES ISLAND.

LOCATION.—In latitude 55° 34′ N., longitude 132° 37′ W., at head of Karta Bay, an arm of Kasaan Bay, on east coast of Prince of Wales Island, 42 miles by water across Clarence Strait from Ketchikan.

DRAINAGE AREA.—49.5 square miles (U. S. Forest Service reconnaissance map of Prince of Wales Island, 1914).

RECORDS AVAILABLE.—July 1, 1915, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on left bank, half a mile above tidewater, at head of Karta Bay and 1½ miles below outlet of Little Salmon Lake. Two per cent of total drainage of Karta River enters between outlet of lake and gage.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across river 50 feet upstream from gage; at low stages by wading at cable section.

CHANNEL AND CONTROL.—From Little Salmon Lake, 1½ miles from tidewater, the river descends 105 feet in a series of rapids in a wide, shallow channel, the banks of which are low but do not overflow. The bed is of coarse gravel and boulders; rock crops out only at outlet of lake. Gage and cable are at a pool of still water formed by a riffle of coarse gravel that makes a well-defined and permanent control.

EXTREMES OF DISCHARGE.—1915–1920: Maximum stage, 5.5 feet November 1, 1917 (discharge, 5,070 second-feet); minimum flow, 21 second-feet, February 11, 1916.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 80 and 1,500 second-feet; extended below 80 second-feet to the point of zero flow and above 1,500 second-feet by estimation. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying gage heights for regular intervals to rating table. Records excellent, except for periods of breaks in record and for discharge above 1,500 second-feet, for which they are fair.

The combined area of Little Salmon Lake at an elevation of 105 feet and Salmon Lake at an elevation of 110 feet is 1,600 acres. The slopes along the right shore of lakes and at head of Salmon Lake are gentle, and the area included by the 250-foot contour above outlet of lake is 5,500 acres. The drainage area below an elevation of 2,000 feet is heavily covered with timber and dense undergrowth of ferns, brush, and alders. The upper parts of the mountains are covered with thin soil and brush. Only a few peaks at an elevation of 3,500 feet are bare. This large lake and flat area and thick vegetal cover afford considerable natural storage, which, after heavy precipitation, maintains a good run-off. The snow usually melts by the end of June, and the run-off becomes very low during a dry, hot summer.

The Forest Service in the summer of 1916 constructed a pack trail from tidewater to outlet of Little Salmon Lake and ran a line of levels to outlet of Little Salmon Lake, the elevation of which was found to be 105 feet above high tide.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Karta River at Karta Bay, for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Aug.	Oct.	Nov.	Dec.
1	454	......	106	180	......	......	......	1,000	448
2	1,110	......	97	160	......	......	......	1,940	350
3	2,430	......	88	142	......	......	......	1,820	364
4	1,570	......	83	132	......	......	......	1,250	468
5	980	......	78	128	......	......	......	860	705
6	714	......	78	128	......	......	......	625	835
7	860	......	81	125	......	......	......	501	748
8	2,060	......	88	118	......	......	......	396	588
9	1,390	......	100	109	......	......	......	326	460
10	916	......	106	103	......	......	......	269	362
11	609	......	142	152	......	......	......	233	302
12	536	......	180	238	......	......	565	192	264
13	494	......	180	254	......	......	705	172	274
14	681	238	172	238	......	......	880	152	280
15	681	224	160	215	......	......	748	132	254
16	543	228	142	192	......	......	588	121	192
17	454	565	142	......	......	......	467	118	248
18	356	765	132	......	......	......	382	118	382
19	296	684	118	......	......	238	308	135	396
20	243	515	109	......	......	......	350	160	350
21	201	402	100	......	......	......	422	238	308
22	......	320	88	......	......	......	460	302	262
23	......	264	83	......	......	......	572	356	229
24	......	220	83	......	......	......	588	501	199
25	......	188	81	......	......	......	665	748	172
26	......	160	78	......	550	......	550	722	192
27	......	145	78	......	......	......	501	588	950
28	......	128	118	......	......	......	480	705	1,420
29	......	115	164	......	......	......	415	665	970
30	......	......	206	......	......	......	338	550	665
31	......	......	201	......	......	......	764	......	665

NOTE.—Water-stage recorder not operating; discharge for following periods estimated from maximum and minimum stages indicated by recorder and by comparison with hydrographs of other stations: Jan. 22–31, 110 second-feet; and Feb. 1–13, 420 second-feet.

Monthly discharge of Karta River at Karta Bay, for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	2,430	......	603	37,100	October 12–31	880	308	537	21,300
February	......	......	366	21,100	November	1,940	118	530	31,500
March	206	78	118	7,260	December	1,420	172	461	28,300
April 1–16	254	103	163	5,170					

BEAVER FALLS CREEK AT GEORGE INLET, REVILLAGIGEDO ISLAND.

LOCATION.—About 200 feet above diversion dam and flume for shingle mill and salmon cannery; 800 feet from beach on west shore of George Inlet; 10 miles by water from Ketchikan.

DRAINAGE AREA.—5.9 square miles (United States Forest Service survey made in 1917).

RECORDS AVAILABLE.—August 3 to October 10, 1917; September 5 to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on left bank, a quarter of a mile from tidewater; reached by a corduroy trail which leaves beach back of cannery buildings. The gage was washed out by high water in November, 1917. A new recorder was installed on September 5, 1920, at a point 8 feet downstream from site of first recorder at datum of August 3, 1917.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from log gaging bridge across stream a quarter of a mile upstream from gage; at low stages made by wading under bridge.

CHANNEL AND CONTROL.—The gage is in a partly sheltered pool in a narrow, deep, rocky canyon, 15 feet upstream from a small rocky fall, which forms a well-defined and permanent control.

DIVERSION.—A small quantity of water is diverted about 200 yards below station into a flume for use of shingle mill and cannery.

ACCURACY.—Stage-discharge relation permanent, but gage well was disturbed by logs and settled probably during high water on August 20, 1917. Rating curve used August 3–19, 1917, and September 5 to December 31, 1920, determined by four discharge measurements and point of zero flow, is well defined below 500 second-feet; curve used August 20 to October 10, 1917, based on two discharge measurements which indicate the amount of change in gage datum caused by settlement of gage well. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for intervals of the day. Records good, except those for periods when gage did not operate satisfactorily, which are fair.

Lower Silvis Lake, whose elevation is 790 feet above high tide, is 1½ miles from the beach, and its area is 62 acres. The elevation of upper Silvis Lake, whose outlet is only 1,100 feet from the upper end of the lower lake, is 1,100 feet above high tide and its area is 234 acres. Drainage area above outlet of lower lake is 4.9 square miles; above outlet of upper lake, 3.6 square miles.

Discharge measurements of Beaver Falls Creek at George Inlet during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Sept. 6	0.76	28
Sept. 8	3.54	365

Daily discharge, in second-feet, of Beaver Falls Creek at George Inlet for the periods Aug. 1 to Oct. 10, 1917, and Sept. 6 to Dec. 31, 1920.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1917.											
1	75	34	142	11	64	14		21	247	175	
2	80	28	283	12	59	48		22	371	132	
3	88	26	223	13	51	97		23	224	86	
4	69	21	352	14	59	193		24	175	168	
5	58	18	183	15	182	234		25	140	244	
6	49	16	97	16	298	164		26	100	144	
7	46	15	69	17	304	97		27	265	323	
8	42	14	52	18	437	152		28	276	305	
9	38	12	76	19	525	90		29	158	212	
10	42	11	152	20	386	97		30	78	107	
								31	47		

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1920.					1920.					1920.				
1		232	300	85	11	194	152	13	19	21	325			11
2		188	500	40	12	176	185	11	20	22	200			9
3		162	300	40	13	100	246	10	25	23	134			8
4		105	200	70	14	105	146	9	25	24	78			7
5		75	100	72	15	170	72	8	19	25	56			7
6	30	51	50	61	16	105	46	8	14	26	56			7
7	140	33	32	56	17	64	32	7	15	27	63			266
8	336	119	26	38	18	45	26	6	18	28	292			278
9	170	432	21	24	19	38	33	7	15	29	164			152
10	92	291	16	20	20	178			13	30	107			94
										31				100

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, by comparison with records of flow for other stations: Aug. 1, 2, and 24–26, 1917, as shown in table; Oct. 20–31, 1920, 180 second-feet; Nov. 1–7, 13–19, and Dec. 1–4, 1920, as shown in table; Nov. 20–30, 1920, 80 second-feet.

Monthly discharge of Beaver Falls at George Inlet for the periods Aug. 1 to Oct. 10, 1917, and Sept. 6 to Dec. 31, 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
1917.					1920.				
August	525	38	162	9,960	September 6–30	336	30	137	6,790
September	323	11	109	6,490	October		26	154	9,470
October 1–10	352	52	163	3,230	November	500		83.5	4,970
					December	278	7	52.5	3,230
					The period				24,500

MAHONEY CREEK AT GEORGE INLET, REVILLAGIGEDO ISLAND.

LOCATION.—One-fourth mile below outlet of Surprise Lake and one-fourth mile above tidewater on west shore of George Inlet, Revillagigedo Island, 3 miles north of Beaver Falls Creek, and 13 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—September 10 to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on right bank of stream one-fourth mile above beach.

DISCHARGE MEASUREMENTS.—At high stages, made from cable across creek 100 yards above gage; at medium and low stages, by wading at cable section or at channel on beach exposed at low tide.

Channel and control.—The gage is at edge of pool between two riffles the lower of which forms a well-defined and permanent control.

Ice.—Stage-discharge relation not affected by ice.

Accuracy.—Stage-discharge relation permanent. Rating curve well defined below but poorly defined above 150 second-feet. Daily discharge ascertained by applying to rating table mean daily gage height determined by inspecting gage-height graph or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for intervals of the day. Records good, except for periods of break in record and discharge above 150 second-feet, for which they are poor.

The Forest Service topographic map of Beaver Falls drainage basin shows the approximate location, outline, and elevation of two important lakes in the Mahoney Creek basin. They are Lower Mahoney Lake, the outlet of which is half a mile from the beach at an elevation of 75 feet above high tide, and Upper Mahoney Lake, the outlet of which is three-fourths mile above head of Lower Mahoney Lake. This lake is about 2,000 feet above high tide and has area of about 180 acres. The discharge at outlet of Upper Mahoney Lake is roughly estimated as 65 per cent of the flow at the gaging station.

Discharge measurements of Mahoney Creek at George Inlet during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Sept. 10	1.42	84
Dec. 3	.95	35
4	1.18	56

Daily discharge, in second-feet, of Mahoney Creek at George Inlet, for the period Sept. 10 to Dec. 31, 1920.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		182	250	70	11	152	127	18	21	21	212	122		14
2		173	400	30	12	157	94	17	22	22	159	104		16
3		127	250	33	13	94	192	16	22	23	105	146		15
4		92	150	55	14	80	130	15	24	24	68			15
5		68	75	58	15	152	82	14	22	25	50			14
6		50	40	54	16	104	53	13	22	26	42			21
7		37	28	56	17	62	37	12	19	27	48			184
8		30	24	47	18	43	28	12	20	28	181			202
9		224	21	35	19	33	26	15	18	29	143			115
10	82	260	19	25	20	76	33		17	30	94			82
										31				88

Note.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, from maximum and minimum stages indicated by recorder and by comparison with records of flow for other stations: Oct. 25-31, 140 second-feet; Nov. 1-6 and 10-19, as shown in table; Nov. 20-30, 70 second-feet; Dec. 1-2, as shown in table.

Monthly discharge of Mahoney Creek at George Inlet for the period Sept. 10 to Dec. 31, 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
September 10-30	212	33	102	4,250	December	202	14	46.3	2,850
October		26	114	7,010	The period				18,400
November	400	12	72.0	4,280					

FISH CREEK NEAR SEA LEVEL, REVILLAGIGEDO ISLAND.

LOCATION.—In latitude 55° 24′ W., near outlet of Lower Lake on Fish Creek, 600 feet from tidewater at head of Thorne Arm, 2 miles northwest of mine at Sea Level, and 25 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 19, 1915, to December 31, 1920.

GAGE.—Stevens water-stage recorder on right shore of Lower Lake, 200 feet above outlet.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across creek, 1 mile upstream from gage and 500 feet above head of Lower Lake; at low stages made by wading at cable. Only one small creek enters Lower Lake, at point opposite gage, between the cable site and control.

CHANNEL AND CONTROL.—The lake is about 500 feet wide opposite the gage. Outlet consists of two channels, each about 60 feet wide, separated by an island 40 feet wide. From the lake to tidewater, 200 feet, the creek falls about 20 feet. Bedrock exposed at the outlet of the lake forms a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 4.9 feet about August 6 (discharge computed from extension of rating curve, 4,110 second-feet); minimum stage, 0.63 foot, March 5 (discharge, 40 second-feet).

1915–1920: Maximum stage recorded, 5.33 feet November 1, 1917 (discharge, 4,600 second-feet); minimum stage, 0.50 foot, February 11, 1916 (discharge, 22 second-feet).

ICE.—Lower Lake freezes over, but as gage is set back in the bank ice does not form in well, and the relatively warm water from the lake and the swift current keep the control open.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined below and extended above 1,500 second-feet. Operation of water-stage recorder satisfactory except for periods shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records good, except for periods of break in record for which they are fair.

A map of the lakes on the drainage basin of this stream was made by the United States Geological Survey in April, 1921. Lower Lake is at an elevation of 15 feet above high tide and has an area of 55 acres; Big Lake is at an elevation of 277 feet and has an area (including lagoon at approximately same elevation) of 358 acres; Third Lake is at an elevation of 324 feet and has an area of 180 acres; Mirror Lake is at an elevation of 377 feet and has an area of about 250 acres; Basin Lake (draining into Big Lake from the east) is at an elevation of 456 feet and has an area of 240 acres.

The following discharge measurement was made by G. H. Canfield:

December 5, 1920: Gage height, 1.32 feet; discharge, 290 second-feet.

Daily discharge, in second-feet, of Fish Creek near Sea Level for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Dec.
1	296	64	74	130	429	......	605	120	......	280
2	368	60	67	114	368	......	502	......	......	225
3	750	78	64	102	346	......	500	......	......	280
4	750	225	60	94	346	......	436	......	......	200
5	506	455	57	89	335	......	390	......	......	281
6	378	756	62	87	680	......	379	......	......	302
7	324	665	74	85	937	......	379	......	......	302
8	581	455	85	80	796	......	368	......	......	265
9	694	357	85	76	650	......	374	......	300	220
10	532	275	89	74	488	......	379	......	302	193
11	414	225	109	130	379	403	374	......	320	176
12	318	200	127	225	335	390	357	......	280	165
13	296	175	130	216	324	379	340	......	260	169
14	563	150	120	170	308	374	324	......	240	172
15	686	120	109	176	291	390	302	509	254	157
16	525	150	96	154	346	403	291	422	......	140
17	395	225	94	140	436	390	275	324	......	140
18	312	297	94	184	......	422	264	264	......	146
19	259	296	92	229	......	436	234	206	......	140
20	217	260	130	234	......	403	220	165	......	133
21	184	216	165	220	......	374	184	154	......	124
22	153	176	140	198	......	379	173	146	......	109
23	136	150	120	184	......	422	157	......	......	96
24	123	130	114	176	......	462	146	......	......	94
25	104	112	107	180	......	436	130	......	......	87
26	97	96	96	335	......	442	120	......	......	99
27	90	89	94	660	......	455	120	......	......	335
28	83	85	109	725	......	483	109	......	......	665
29	76	80	124	628	......	598	102	......	......	628
30	65	......	140	520	......	658	102	......	......	488
31	65	......	140	......	......	......	106	......	......	530

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, from records of flow for other stations: Jan. 26–28, discharge interpolated; Feb. 11–17, daily discharge as given in table (maximum and minimum stages indicated by recorder); May 18–31, 375 second-feet; and June 1–10, 600 second-feet (maximum and minimum stages for the period indicated by the recorder); Aug. 2–14, 1,100 second-feet; Aug. 23–31, 150 second-feet; Sept. 1–8, 240 second-feet; Sept. 11–14, daily discharge Sept. 16–30, 310 second-feet; Oct. 1–31, 460 second-feet; Nov. 1–30, 400 second-feet; Dec. 1–4, daily discharge

Monthly discharge of Fish Creek near Sea Level for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	750	65	333	20,500	August	......	......	581	35,700
February	756	60	228	13,100	September	......	......	289	17,200
March	165	57	102	6,270	October	......	......	460	28,300
April	725	74	220	13,100	November	......	......	400	23,800
May	937	......	421	25,900	December	665	87	233	14,300
June	......	......	490	29,200					
July	605	102	284	17,500	The year	......	......	337	245,000

SWAN LAKE OUTLET AT CARROLL INLET, REVILLAGIGEDO ISLAND.

Location.—Halfway between Swan Lake and tidewater, on east shore of Carroll Inlet 1 mile from its head, 30 miles by water from Ketchikan.

Drainage area.—Not measured.

Records available.—August 24, 1916, to December 31, 1920.

Gage.—Stevens water-stage recorder on left bank, half a mile from tidewater; reached by a trail which leaves beach back of old cabin one-fourth mile south of mouth of creek. Gage was washed out by extreme high water in November, 1917. New gage installed 10 feet farther back in bank at old datum, but with a new control, on May 5, 1918.

Discharge measurements.—At medium and high stages, made from a cable across stream 100 feet downstream from gage; at low stages, made by wading.

Channel and control.—The gage well is in a deep pool 25 feet upstream from a contracted portion of the channel, where a fall of 1 foot over bedrock forms a permanent control. The effect of the violent fluctuation of the water surface outside of the gage well is decreased in the inner float well, because the intake holes at the bottom are very small. At the cable section the bed is rough, the water shallow, and the current very swift. Point of zero flow is at gage height —1.0 foot.

Extremes of discharge.—Maximum stage during year, from water-stage recorder, 5.50 feet at noon, August 6 (discharge, computed from extension of rating curve, 2,800 second-feet); minimum stage, 0.23 foot April 10 (discharge, 62 second-feet).

1915–1920: Maximum stage occurred probably on November 1, 1917 (discharge, estimated by comparison with Fish Creek, 5,500 second-feet); minimum discharge, 36 second-feet, March 19–20, 1919.

Ice.—Stage-discharge relation not affected by ice.

Accuracy.—Stage-discharge relation permanent. Rating curve, determined by six discharge measurements and point of zero flow, is fairly well defined below 2,000 second-feet. Water-stage recorder operated satisfactorily except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharges obtained by applying to rating table mean gage heights for regular intervals of day. Records good, except for periods of break in record, for which they are fair.

No maps of the entire drainage basin of this stream are available. The United States Forest Service in the fall of 1920 made a survey consisting of stadia traverse between the beach and Swan Lake, by which the elevation was determined as 220 feet above high tide; triangulation of lake, by which area of lake was determined as 1,325 acres; topography of lake shore below an elevation of 350 feet and of stream between lake and proposed dam site, two-thirds mile below outlet of lake, where elevation of bed of stream is 170 feet; cross section at dam site; and topography along proposed conduit about 300 feet long on south side of creek. Blue-print copies of the map of this survey may be obtained from the offices of the United States Forest Service at Portland, Oreg., or Ketchikan, Alaska.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Swan Lake outlet at Carroll Inlet for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	69	89	94	433	585	701	188	331	820	......	308
2	......	66	85	85	397	698	639	288	325	1,050	......	271
3	......	78	80	79	380	820	513	277	280	1,020	......	254
4	......	196	76	74	352	902	469	962	251	770	......	277
5	......	425	73	72	368	875	469	2,170	216	608	......	277
6	......	644	72	72	593	795	425	2,600	186	485	......	271
7	337	608	89	69	765	698	390	1,890	218	......	......	265
8	565	445	94	68	657	650	371	1,140	585	......	......	260
9	537	343	92	63	501	575	361	688	567	......	......	248
10	404	277	99	64	400	525	401	450	425	......	......	229
11	331	246	158	122	343	500	457	1,200	384	......	......	208
12	282	224	152	165	328	485	441	1,800	364	......	......	190
13	303	193	135	151	315	470	425	1,300	331	......	......	176
14	497	170	116	137	297	460	401	990	303	......	......	170
15	505	152	105	126	315	485	394	648	340	......	......	161
16	380	161	94	118	390	500	374	461	358	......	......	150
17	300	240	90	109	418	525	352	343	340	......	......	141
18	254	262	87	213	485	626	307	274	300	......	......	139
19	213	254	84	213	473	603	280	210	271	......	......	132
20	176	226	99	198	384	485	235	172	282	......	......	128
21	156	193	105	181	328	449	213	156	565	......	183	124
22	139	172	94	170	303	422	193	145	585	......	181	116
23	122	154	89	165	291	453	170	145	485	......	218	111
24	111	137	89	170	297	437	150	143	390	......	243	103
25	101	122	85	226	322	418	135	139	328	......	309	96
26	94	111	80	448	343	505	126	145	282	......	343	130
27	85	103	82	790	364	545	122	174	254	......	337	141
28	79	98	145	745	346	648	112	172	374	......	331	621
29	76	94	122	630	358	765	111	165	489	......	328	541
30	73	......	120	513	445	795	128	154	461	......	322	422
31	72	......	103	......	537	......	161	246	......	......	......	368

NOTE.—Discharge for following periods estimated, because of unsatisfactory operation of water-stage recorder, from maximum and minimum stages indicated by recorder and by comparison with hydrographs and records of flow for other stations: Jan. 1-6, 450 second-feet; Apr. 13, June 8-16, and Aug. 10-13, as given in table; Oct. 7-31, 550 second-feet; Nov. 1-20, 500 second-feet.

Monthly discharge of Swan Lake outlet at Carroll Inlet for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	......	72	287	17,600	August	2,600	139	640	39,400
February	644	66	223	12,800	September	585	186	362	21,500
March	158	72	99.5	6,120	October	......	......	597	36,700
April	790	63	211	12,600	November	......	......	426	25,300
May	765	291	404	24,800	December	621	96	227	14,000
June	902	422	590	35,100					
July	701	111	323	19,900	The year	2,600	63	366	266,000

ORCHARD LAKE OUTLET AT SHRIMP BAY, REVILLAGIGEDO ISLAND.

LOCATION.—In latitude 55° 50′ N., longitude 131° 27′ W., at outlet of Orchard Lake one-third mile from tidewater at head of Shrimp Bay, an arm of Behm canal, 46 miles by water from Ketchikan.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 28, 1915, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on right bank 300 feet below Orchard Lake and 100 feet above site of timber-crib dam, which was built in 1914 for proposed pulp mill and washed out by high water August 10, 1915. Datum of gage lowered 2 feet September 15, 1915. Gage heights May 29 to August 10

referred to first datum; August 11, 1915, to August 17, 1916, to second datum. Datum of gage lowered 1 foot August 17, 1916. Gage heights August 18 to December 31, 1916, referred to this datum. Gage washed out probably during high water on November 1, 1917. New gage installed on April 28, 1918, at old site at the datum of August 17, 1916.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable 5 feet upstream from gage; at low stages by wading one-fourth mile below gage.

CHANNEL AND CONTROL.—From Orchard Lake, at elevation 134 feet above high tide, the stream descends in a series of rapids for 1,000 feet through a narrow gorge, then divides into two channels and enters the bay in two cascades of 100-foot vertical fall. Opposite the gage the water is deep and the current sluggish. At the site of the old dam bedrock is exposed, but for 30 feet upstream the channel is filled in with loose rock and brush placed during construction of dam. This material forms a riffle, which acts as a control for water surface at gage at low and medium stages and is scoured down when ice goes out of lake; the rock outcrop at site of old dam acts as a control at high stages and is permanent.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 8.0 feet at 2 p. m. August 6 (discharge 4,780 second-feet); minimum stage, 0.31 foot March 9 (discharge, 67 second-feet).

1915–1920: Maximum stage probably occurred on November 1, 1917 (discharge estimated by multiplying maximum discharge at Fish Creek on that date by 1.55, which is the ratio between the maximum discharges of Orchard Lake outlet and Fish Creek on October 15 and 16, 1915, 7,100 second-feet); minimum discharge, estimated, 20 second-feet, February 11, 1916.

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation changes occasionally during high water. Rating curve, determined by seven discharge measurements made since new gage was installed, point of zero flow, and form of upper portion of old rating curve, is well defined below 4,000 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharges obtained by applying to rating table mean gage heights for regular intervals of day. Records good, except for period of break in record, for which they are fair.

The highest mountains on this drainage basin are only 3,500 feet above sea level and are covered to an elevation of 2,500 feet by a heavy stand of timber and a thick undergrowth of brush, ferns, alders, and devil's club. The topography is not so rugged as that of the area surrounding Shelockum Lake, and the proportion of vegetation, soil cover, and lake area is greater, so that more water is stored in the Orchard Lake drainage basin and the flow is better sustained.

A survey of Orchard Lake was made by an engineering company in September, 1920. From this survey the area of the lake was determined as 965 acres and the elevation of lake above high tide as 128 feet. A dam at the outlet of the lake would flood part of the valley, at the head of the lake, which extends upstream a few miles at a small gradient.

Discharge measurements of Orchard Lake outlet at Shrimp Bay during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
Feb. 16	0.72	135
Dec. 8	1.48	285

Daily discharge, in second-feet of Orchard Lake outlet at Shrimp Bay, for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Dec.
1	259		85		680	1,080	1,030	314	400	350
2	422		81		640	1,250	880	447	410	275
3	700		79		624	1,430	740	560	368	300
4	514		74		560	1,460	708	1,210	338	300
5	362		75		572	1,400	724	3,290	280	290
6	270		75		870	1,220	762	4,560	242	285
7	394		72		1,060	1,030	808	2,900	242	290
8	808		68		905	905	808	1,370	680	275
9	616		67		700	855	785	785	762	225
10	430				572	808	785	522	560	190
11	320				492	740	762	1,240	450	162
12	252				485	740	700	2,410	390	140
13	335				485	740	660	2,100	308	134
14	640				467	785	620	1,160	275	130
15	533				510	855	592	700	332	120
16	387	119			680	785	572	474	362	109
17	288	166			700	808	511	350	338	105
18	218	275			740	930	450	272	280	119
19	186	286			740	720	487	225	280	134
20	176	254			612	612	326	196	384	138
21		199			507	596	297	176	600	136
22		166			481	680	270	209	540	125
23		141			500	680	232	314	407	110
24		119		267	588	640	212	297	286	102
25		109		329	640	640	190	247	230	92
26		100		955	640	785	190	267	190	105
27		93		1,280	660	855	190	350	170	810
28		89		1,160	640	930	184	329	340	1,000
29		87		980	680	1,110	186	262	650	660
30				785	920	1,160	192	218	500	457
31					1,000		280	280		433

NOTE.—Discharge estimated for following periods, because water-stage recorder was run down or not operating satisfactorily: Jan. 21–31, 105 second-feet; Feb. 1–15, 350 second-feet; Mar. 10–31, 100 second-feet; Apr. 1–23, 160 second-feet. Discharge for following periods estimated from maximum and minimum stages indicated by recorder and comparison with hydrographs for streams in near-by drainage basins and climatic data for Ketchikan; May 27–28, June 18–22, and Sept. 26–30, daily discharge as shown in table; Oct. 1–31, 630 second-feet; Nov. 1–30, 520 second-feet; Dec. 1–8 by comparison with record of flow for the outlet of Shelockum Lake.

Monthly discharge of Orchard Lake outlet at Shrimp Bay, for 1920.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.
January			299	18,400
February		87	257	14,800
March			92.8	5,710
April	1,280		315	18,700
May	1,060	467	656	40,300
June	1,460	596	908	54,000
July	1,030	184	520	32,000
August	4,560	176	904	55,600
September	762	170	386	23,000
October			630	38,700
November			520	30,900
December	1,000	92	261	16,000
The year	4,560		480	348,000

SHELOCKUM LAKE OUTLET AT BAILEY BAY.

LOCATION.—In latitude 56° 00′ N., longitude 131° 36′ W., on mainland near outlet of Shelockum Lake, three-fourths mile by Forest Service trail from tidewater at north end of Bailey Bay and 52 miles by water north of Ketchikan.

DRAINAGE AREA.—18 square miles (measured on sheets Nos. 5 and 8 of the Alaska Boundary Tribunal, edition of 1895).

RECORDS AVAILABLE.—June 1, 1915, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on right shore of lake, 250 feet above outlet.

DISCHARGE MEASUREMENTS.—Made from cable across outlet of lake, 200 feet below gage and 50 feet upstream from crest of falls.

CHANNEL AND CONTROL.—Opposite the gage the lake is 600 feet wide; at the outlet bedrock is exposed and the water makes a nearly perpendicular fall of 150 feet. This fall forms an excellent and permanent control for the gage. At extremely high stages the lake has another outlet about 200 feet to left of main outlet. Point of zero flow is at gage height 0.6 foot.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 6.65 feet, at 9 a. m. August 6 (discharge, 2,580 second-feet); minimum discharge (estimated from hydrograph for Fish Creek to have occurred March 9), 15 second-feet.

1915–1920: Maximum stage, 6.84 feet at 8 a. m. November 1, 1917 (discharge, 2,780 second-feet); minimum discharge, estimated from climatic records, 2.5 second-feet.

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined. Operation of water-stage recorder satisfactory except for periods of break in record, as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspection of gage-height graph, or, for days of considerable fluctuation, by averaging discharges obtained by applying to rating table mean gage heights for regular intervals of day. Records excellent, except for periods of break in record, for which they are fair.

An outline survey of Shelockum Lake was made in 1914 by the United States Forest Service, and blue-print copies of the survey can be obtained from their district office at Ketchikan. This survey ascertained the lake to be 344 feet above high tide and 350 acres in area. The drainage basin above the lake is rough, precipitous, and covered with little soil or vegetation. There are no glaciers or ice fields at the source of the tributary streams. Therefore, because of little natural storage, the run-off after a heavy rainfall is rapid and not well sustained, and during a dry summer or winter the flow becomes very low. The large amount of snow that accumulates on the drainage basin during the winter maintains a good flow in May and June.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Shelockum Lake outlet at Bailey Bay for 1920.

Day.	Jan.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	106	....	230	472	422	273	363	263	761	94
2	134	....	224	525	336	321	304	314	1,320	76
3	206	....	226	600	292	282	233	336	660	82
4	170	....	216	600	297	748	214	243	350	82
5	127	....	204	580	350	1,640	166	172	241	80
6	111	....	230	508	392	2,300	128	125	164	76
7	164	....	230	438	407	950	150	92	123	76
8	316	....	210	405	407	392	525	72	97	75
9	252	....	174	377	407	237	392	280	78	60
10	190	....	154	377	392	166	241	525	67	59
11	150	....	147	358	363	736	182	324	58	55
12	123	....	196	377	350	1,250	160	210	50	50
13	134	....	204	350	318	660	128	210	43	53
14	289	....	194	363	309	336	112	239	38	55
15	297	....	220	392	292	214	117	210	34	52
16	208	....	331	392	275	145	104	156	31	47
17	158	....	306	363	252	112	94	120	30	43
18	121	....	336	472	220	84	91	94	29	43
19	92	....	306	363	190	71	115	78	31	44
20	76	....	241	311	164	60	141	170	59	44
21	56	....	200	287	149	71	252	275	88	43
22	53	....	192	324	136	123	235	263	100	41
23	48	....	210	336	120	145	174	270	98	37
24	43	85	241	297	110	123	127	275	109	35
25	40	123	273	292	98	98	94	268	123	31
26	38	342	270	336	98	154	80	230	152	33
27	35	422	268	363	96	299	72	378	132	194
28	33	378	245	490	92	241	143	363	127	392
29	31	311	280	580	94	170	265	252	136	268
30	30	263	378	542	115	123	212	186	117	184
31	28	....	455	....	230	210	....	275	....	145

NOTE.—Record traced by recording pencil Jan. 22, 23, 25–27, 30, and 31, too faint to be seen; discharge estimated. No record Feb. 1 to Apr. 23, except maximum stage; discharge estimated from records of flow for streams in near-by drainage basins: Feb. 1–28, 65 second-feet; Mar. 1–31, 30 second-feet; Apr. 1–23, 40 second-feet.

Monthly discharge of Shelockum Lake outlet at Bailey Bay for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	316	28	125	7,690	August	2,300	60	411	25,300
February	....	....	65	3,740	September	525	72	187	11,100
March	....	....	30	1,840	October	525	72	234	14,400
April	422	....	94.8	5,640	November	1,320	29	182	10,800
May	455	147	245	15,100	December	392	31	85.7	5,270
June	600	287	416	24,800					
July	422	92	251	15,400	The year	2,300	....	194	141,000

CASCADE CREEK AT THOMAS BAY, NEAR PETERSBURG.

LOCATION.—One-fourth mile above tidewater on east shore of south arm of Thomas Bay, 22 miles by water from Petersburg. One small tributary enters the river from the left half a mile above gage and 2 miles below outlet of lake.

DRAINAGE AREA.—21.4 square miles (measured on the United States Geological Survey geologic reconnaissance map of the Wrangell mining district, edition of 1907).

RECORDS AVAILABLE.—October 27, 1917, to December 31, 1920.

GAGE.—Stevens water-stage recorder on left bank, one-fourth mile from tidewater; reached by trail which leaves beach back of old cabin at mouth of creek.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from log footbridge across stream one-fourth mile upstream from gage; at low stages, made by wading

CHANNEL AND CONTROL.—Gage is in a protected eddy above a natural rock weir, which forms a well-defined and permanent control. The bed of river under the footbridge is rough and the current swift and irregular, but this section is the only place on the whole river where even at low and medium stages there are no boils and eddies.

EXTREMES OF STAGE.—Maximum stage recorded during period of records, 8.4 feet at 6 a. m. August 6, 1920 (discharge computed from extension of rating curve, 2,540 second-feet); minimum stage, 0.80 foot about April 6, 1918 (discharge, 17 second-feet).

ICE.—Stage-discharge relation not affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined below 1,200 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharge for equal intervals of day. Records good, except for periods when recorder did not operate satisfactorily, for which they are fair.

The first site on this stream for a storage reservoir is at a small lake 3 miles from tidewater, at an elevation of 1,200 feet above sea level. The drainage area above the gaging station is 21 square miles and above the outlet of the lake 17 square miles. Flow during summer is augmented by melting ice from glaciers on upper part of drainage area.

The only maps available, showing the drainage basin of this stream, are sheet 10 (scale, 1: 160,000) of the Alaska Boundary Tribunal, edition of 1895; topographic map of the Wrangell mining district (scale, 1: 250,000) of the United States Geological Survey, edition of 1907 (topography compiled from sheets of the Alaska Boundary Tribunal). A rough map, made for J. T. Martin who has mining claims near the mouth of the stream, shows a very small lake, 1.7 miles upstream from beach at an elevation of 1,250 feet; a small flat, 2.1 miles upstream from beach, at an elevation of 1,600 feet; and a lake (not surveyed but estimated to be 2 miles long by three-fourths mile wide) 2.5 miles upstream from beach, at an elevation of 1,950 feet.

The first lake and the flat are too small for storage reservoirs. A storage reservoir having a capacity sufficient to equalize the flow could probably be created by a tunnel or dam at the outlet of the large lake. The drainage area between the outlet of this lake and the gaging station is 4.5 square miles.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, of Cascade Creek at Thomas Bay for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	70			24	48	365	640	518	380	160	455	40
2	99			25	52	440	552	500	395	153	622	39
3	131			24	55	518	470	470	500	144	425	38
4	107			24	48	570	485	775	570	129	292	37
5	93			24	48	600	535	1,720	535	119	210	37
6	86			24	52	600	570	2,460	440	144	192	36
7	130			24	51	550	622	1,370	305	124	153	35
8	192			24	48	530	675	870	210	119	129	33
9	134			24	48	500	675	570	160	200	114	32
10	117			23	49	470	675	425	150	160	104	31
11	103			25	57	450	675	1,160	150	134	92	30
12	88			39	76	420	675	1,810	119	119	79	29
13	93			31	66	395	622	1,370	111	129	70	28
14	109			27	65	404	605	932	109	124	65	27
15	90			26	86	455	622	622	111	111	62	26
16	77			26	113	440	675	440	250	94	56	26
17	67			25	112	425	658	342	455	81	53	26
18				27	119	425	605	280	368	70	52	29
19				26	108	355	570	300	368	72	50	29
20				26	100	305	535	280	500	122	55	27
21				28	95	280	500	395	470	119	70	26
22				29	99	318	470	410	380	114	54	26
23				29	105	292	425	342	342	206	52	25
24				32	112	250	368	250	355	153	53	26
25			25	80	114	260	355	220	440	127	54	24
26			25	86	121	318	395	440	588	167	48	30
27			25	68	136	395	440	535	470	355	45	114
28			25	56	153	518	440	410	318	260	48	53
29			25	60	192	675	470	292	230	192	47	46
30			25	48	250	710	470	230	183	318	42	44
31			25		305		552	270		368		31

NOTE.—Discharge estimated for following periods, because of unsatisfactory operation of water-stage recorder, by comparison with hydrograph and record of flow for Sweetheart Falls Creek: Jan. 1, 70 second-feet; Jan. 18–31, 45 second-feet; Feb. 1–29, 60 second-feet; Mar. 1–24, 35 second-feet; and June 5–12, as shown in table.

Monthly discharge of Cascade Creek at Thomas Bay for 1920.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.	Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.
January	192		77.9	4,790	August	2,460	220	676	41,600
February			60	3,450	September	588	109	332	19,800
March			32.7	2,010	October	368	70	158	9,720
April	86	23	34.1	2,030	November	622	42	128	7,620
May	305	48	99.4	6,110	December	114	24	34.8	2,140
June	710	250	441	26,200					
July	675	355	549	33,800	The year	2,460	23	219	159,000

GREEN LAKE OUTLET AT SILVER BAY, NEAR SITKA.

LOCATION.—In latitude 56° 59′ N., longitude 135° 5′ W., at outlet of Green Lake, head of Silver Bay, 10½ miles by water south of Sitka.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—August 22, 1915, to December 31, 1920.

GAGE.—Stevens water-stage recorder on right bank, at outlet of lake, reached by trail which leaves the beach one-fourth mile north of mouth of stream, ascends a 600-foot ridge, and then drops down to the outlet of the lake. Gage datum lowered 1 foot December 27, 1916.

DISCHARGE MEASUREMENTS.—Made from cable across outlet 30 feet below gage.

CHANNEL AND CONTROL.—From Green Lake, 240 feet above sea level and 1,800 feet from tidewater, the stream descends in a series of falls and rapids through a narrow canyon whose exposed rock walls rise vertically more than 100 feet.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 10.0 feet, at 11 a. m. August 5 (discharge, computed from extension of rating curve, 1,900 second-feet); minimum stage recorded, −0.05 foot, estimated from hydrographs for other stations to have occurred April 10 (discharge, 10 second-feet).

1915–1920: Maximum stage recorded, 13.0 feet, September 26, 1918 (discharge, estimated from extension of rating curve, 3,300 second-feet); minimum stage recorded, −0.05 foot, estimated from hydrographs for other stations to have occurred April 10, 1920 (discharge, 10 second-feet).

ICE.—Ice forms on lake and at gage, but because of current and flow of relatively warm weather from the lake the control remains open.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 10 and 1,300 second-feet. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record, as shown in the footnote to the daily-discharge table. Daily discharge ascertained by applying to the rating table mean daily gage height, determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Records good, except those for periods when gage was not operating satisfactorily, which are fair.

No maps have been made of the drainage basin. The elevation of Green Lake above high tide, measured by aneroid barometer, is 240 feet; the area of the lake is 175 acres, according to the best available estimates. At the upper end of lake is a low flat, reported to be 2 or 3 miles long, which would be flooded by a dam at outlet of lake.

The following discharge measurement was made by G. H. Canfield:

June 18, 1920: Gage height, 4.36 feet; discharge, 466 second-feet.

Daily discharge, in second-feet, of Green Lake outlet at Silver Bay, for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Oct.	Nov.	Dec.
1	......	......	38	16	......	406	547	452	......	820	100
2	......	......	30	14	......	499	452	442	......	1,480	90
3	......	......	26	12	......	695	397	397	......	751	90
4	......	......	20	16	......	889	397	470	......	380	90
5	......	......	20	......	......	706	424	1,640	......	320	80
6	212	......	20	......	......	518	461	1,220	......	774	73
7	1,590	......	26	......	......	442	547	672	......	461	70
8	1,350	......	26	......	......	490	588	442	......	278	65
9	464	......	26	......	......	528	568	320	......	200	60
10	254	......	30	......	......	461	537	328	......	161	55
11	206	......	40	......	......	397	518	706	......	134	50
12	147	......	42	......	......	406	557	599	......	116	50
13	118	......	40	......	......	388	518	673	......	106	50
14	118	......	36	......	......	424	490	518	......	93	50
15	107	......	30	......	......	518	499	354	......	86	40
16	90	......	30	......	303	461	461	270	......	76	40
17	72	......	33	......	247	433	424	240	......	75	40
18	60	......	28	......	206	461	406	210	......	71	40
19	54	......	26	......	166	397	406	200	......	72	35
20	53	......	20	......	134	328	415	215	......	82	35
21	48	......	18	......	118	294	406	260	240	90	30
22	46	72	16	......	114	461	371	294	200	80	30
23	......	60	16	......	122	499	320	......	337	80	30
24	......	54	16	......	126	371	270	......	270	90	25
25	......	49	16	......	161	328	270	......	188	80	25
26	......	48	16	......	303	433	320	......	303	70	50
27	......	44	23	......	262	499	354	......	424	65	150
28	......	42	40	......	262	537	415	......	286	175	275
29	......	40	38	......	328	547	499	......	194	200	212
30	......	......	30	......	380	568	490	......	885	140	134
31	......	......	20	......	371	......	480	......	620	......	118

NOTE.—Discharge for following periods when water-stage recorder was run down or not operating satisfactorily estimated by comparison with hydrographs of streams in near-by drainage basins and climatic data for Juneau: Jan. 1-5, 280 second-feet; Jan. 23-31, 38 second-feet; Apr. 5-30, 45 second-feet; May 1-15, 115 second-feet. Discharge for following periods estimated by comparison with record of flow for Sweetheart Falls Creek near Snettisham: Aug. 18-21, daily discharge; Aug. 23-31, 290 second-feet; Sept. 1-30 330 second-feet; Oct. 1-20, 240 second-feet; Nov. 21-30, Dec. 1-5, and 7-28, daily discharge.

Monthly discharge of Green Lake outlet at Silver Bay for 1920.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.	Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.
January	1,590	....	217	13,300	August	1,640	....	437	26,900
February	....	....	82.9	4,770	September	....	....	330	19,600
March	42	16	27.0	1,660	October	885	188	282	17,300
April	....	....	40.9	2,430	November	1,480	65	254	15,100
May	380	....	172	10,600	December	275	25	73.6	4,530
June	889	294	479	28,500					
July	588	270	445	27,400	The year	1,640	....	237	172,000

BARANOF LAKE OUTLET AT BARANOF, BARANOF ISLAND.

LOCATION.—In latitude 57° 5′ N., longitude 134° 54′ W., at townsite of Baranof, at head of Warm Spring Bay, east coast of Baranof Island, 18 miles east of Sitka across island, but 96 miles from Sitka by water through Peril Strait.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—June 28, 1915, to December 31, 1920.

GAGE.—Stevens water-stage recorder on right bank 700 feet below Baranof Lake and 800 feet above tidewater at head of Warm Spring Bay.

DISCHARGE MEASUREMENTS.—At medium and high stages, from cable across stream 100 feet below lake and 600 feet above gage; at low stages, by wading 100 feet below cable.

CHANNEL AND CONTROL.—From Baranof Lake, at elevation 130 feet above sea level and 1,500 feet from tidewater, the stream descends in a series of rapids and small falls and enters the bay in a cascade of about 100-foot concentrated fall. The bed is of glacial drift, boulders, and rock outcrop. The gage is in an eddy 50 feet downstream from the foot of a small fall and 100 feet upstream from a riffle which forms a well-defined control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 4.3 feet at noon, November 2 (discharge, 2,000 second-feet); minimum discharge, estimated, 32 second-feet, April 14.

1915–1920: Maximum stage recorded during period, 5.3 feet August 10, 1915 (discharge, computed from extension of rating curve, 3,350 second-feet); minimum discharge, estimated by discharge measurement and climatic data, 28 second-feet, February 13, 1915.

ICE.—Because of the swift current and flow of relatively warm water from the lake, the stream remains open except during extremely cold periods.

DIVERSIONS.—The flume to Olsen's sawmill diverts from the stream 200 feet below gage only sufficient water to operate a 25-horsepower Pelton water wheel.

ACCURACY.—Stage-discharge relation permanent; slightly affected by ice March 29 to April 19. Rating curve well defined below 2,000 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharge for equal intervals of day. Records good, except for periods when recorder did not operate satisfactorily and for periods when water was frozen in well, for which they are fair.

The drainage area is rough and precipitous, and the vegetable and soil cover is thin, even on the foothills of the mountains. The run-off is rapid, and the ground storage is small. During a hot, dry period, however, the flow is greatly augmented by melting ice from several small glaciers and ice-capped mountains.

The drainage basin of this stream has not been surveyed, but Baranof Lake and the region between lake and tidewater at head of Warm Spring Bay was surveyed and map drawn in 1914 by the United States Forest Service. Blue-print copies can be obtained from the district office of the Forest Service at Juneau, Alaska. The elevation of Baranof Lake above high tide as determined by the survey was 134 feet and the area of the lake 700 acres.

It would be necessary to raise the elevation of the lake 100 feet in order to create a reservoir having a capacity of 90,000 acre-feet, the storage required to equalize the flow.

No discharge measurements were made at this station during the year.

Daily discharge, in second-feet, Baranof Lake outlet at Baranof, for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	......	......	52	33	205	695	788	680	590	668	1,330
2	......	......	51	33	189	755	695	660	522	545	1,940
3	......	......	48	33	210	855	615	590	615	436	......
4	......	......	47	32	235	1,010	640	668	640	362	......
5	......	......	43	34	220	1,010	725	1,330	500	303	......
6	......	......	45	35	203	890	788	1,380	432	255	......
7	......	165	45	37	195	788	970	890	890	208	......
8	......	149	47	39	185	820	1,010	695	930	189	......
9	......	129	49	40	181	820	970	545	640	348	......
10	......	118	49	43	183	725	930	480	500	400	......
11	309	145	49	43	203	695	930	668	500	324	......
12	255	137	51	43	220	668	1,050	725	420	273	......
13	218	118	56	43	238	615	1,010	640	460	267	......
14	195	106	57	42	248	640	930	590	336	250	......
15	169	95	54	42	291	725	855	492	270	225	......
16	145	102	53	42	327	695	820	420	225	195	......
17	125	125	52	47	339	668	755	370	191	171	......
18	110	129	52	84	336	668	695	352	185	155	......
19	95	118	51	90	309	615	668	408	230	141	......
20	......	102	49	84	285	545	668	460	205	199	......
21	......	89	46	82	261	522	640	452	177	264	......
22	......	80	44	80	242	640	568	420	173	300	......
23	......	70	40	83	242	615	500	362	169	366	......
24	......	64	39	100	250	545	460	321	167	350	......
25	......	61	39	114	315	545	500	291	155	270	......
26	......	59	36	141	568	615	600	362	147	345	......
27	......	55	36	167	568	695	650	678	137	488	......
28	......	53	36	187	568	820	725	615	324	400	......
29	......	53	34	195	615	820	850	444	1,100	330	......
30	......	......	34	208	695	855	800	392	392	772	......
31	......	......	31	......	695	......	750	640	......	930	......

NOTE.—Discharge for following periods estimated, because of ice effect or unsatisfactory operation of water-stage recorder, by comparison with hydrographs for streams in near-by drainage basins and climatic data for Juneau: Jan. 1–10, 455 second-feet; Jan. 20–31, 70 second-feet; Feb. 1–6, 90 second-feet; and Mar. 29 to Apr. 9, daily discharge. Daily discharge, July 25 to Aug. 2, estimated by comparison with record of flow for outlet of Green Lake; discharge for following periods estimated from records for Sweetheart Falls Creek: Sept. 12–20, daily discharge; Nov. 3–30, 290 second-feet; Dec. 1–31, 55 second-feet.

Monthly discharge of Baranof Lake outlet at Baranof for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
January	......	......	226	13,900
February	165	53	98.7	5,680
March	57	34	45.7	2,810
April	208	32	75.9	4,520
May	695	181	317	19,500
June	1,010	522	719	42,800
July	1,050	460	760	46,700
August	1,380	291	581	35,700
September	1,100	137	407	24,200
October	930	141	346	21,300
November	1,940	......	380	22,600
December	......	......	55	3,380
The year	1,940	32	335	243,000

FALLS CREEK AT NICKEL, NEAR CHICHAGOF.

LOCATION.—One-eighth mile above beach, on stream that enters tidewater half a mile northeast of camp of Alaska Nickel Mines Co., 20 miles by water northwest of Chichagof, on west coast of Chichagof Island.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 6, 1918, to June 13, 1920.

GAGE.—Stevens water-stage recorder on left bank one-eighth mile above beach.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from cable across stream 500 feet above gage; at low stages, made by wading in channel exposed at beach at low tide.

CHANNEL AND CONTROL.—The gage is 20 feet upstream from rectangular weir, the crest of which is 2 feet above bed of stream, 2 inches wide, and 40 feet long. At the cable section the bed is smooth, the water is deep, and the current is regular and sluggish.

EXTREMES OF DISCHARGE.—1918–1920: Maximum stage recorded during period, 3.45 feet at 3 p. m. September 26, 1918 (discharge, 665 second-feet); minimum stage recorded, 0.18 foot March 12, 1919 (discharge, 3.2 second-feet).

ICE.—Stage-discharge relation affected by ice forming on crest of weir for short periods during extremely cold weather.

ACCURACY.—Stage-discharge relation changed February 17, 1920, when the river was disturbed by ice, the average elevation of crest of weir being raised about 0.11 foot. Rating curves used before and after the change fairly well defined between 30 and 100 second-feet; extended beyond those limits by use of formula the coefficient for which was based on results of current-meter measurements. Operation of water-stage recorder satisfactory except for periods shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage height obtained by inspection of gage-height graph or for days of considerable variation in stage by averaging discharge for intervals of the day. Records fair.

COOPERATION.—Station maintained in cooperation with the Alaska Nickel Mines Co.

The following discharge measurement was made by G. H. Canfield:
June 14, 1920: Gage-height, 0.66 foot; discharge, 45 second-feet.

Daily discharge, in second-feet, of Falls Creek at Nickel for the period May 6, 1918, to June 13, 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918.												
1						115	106	49	215	52	128	235
2						95	83	44	120	50	88	179
3						83	71	40	62	70	66	115
4						76	63	37	44	72	85	85
5						76	56	35	39	61	465	74
6					120	81	49	42	34	52	358	101
7					92	90	46	58	31	58	191	62
8					85	102	43	50	28	50	115	51
9					84	104	41	54	79	56	81	47
10					85	94	38	42	60	41	62	41
11					95	96	57	39	50	39	66	37
12					101	94	60	37	44	96	86	34
13					101	85	50	52	41	85	68	30
14					100	79	44	100	37	120	62	31
15					92	76	40	68	50	86	50	29
16					86	68	37	68	62	68	49	58
17					78	62	35	92	174	86	43	68
18					79	58	32	72	235	101	35	60
19					71	54	30	68	156	75	31	52
20					62	58	30	72	100	72	47	43
21					68	56	28	109	72	65	68	143
22					62	51	26	137	56	52	79	137
23					62	50	25	162	94	49	82	156
24					62	57	25	217	68	56		117
25					66	63	24	181	166	52		130
26					70	66	23	128	414	115		115
27					71	68	35	104	271	86		82
28					203	68	54	150	150	156		62
29					258	115	39	156	96	134		54
30					197	162	44	360	66	152		46
31					164		57	408		137		41

Daily discharge, in second-feet, of Falls Creek at Nickel for the period May 6, 1918, to June 13, 1920—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1919.												
1	47	......	9	......	......	40	23	15	60	37	42	17
2	115	......	9	......	......	46	22	14	41	241	29	15
3	89	......	9	......	......	49	26	14	22	420	24	15
4	78	......	8	51	31	47	30	14	26	345	21	18
5	92	......	8	56	......	46	30	20	20	345	17	23
6	229	......	11	56	......	44	42	16	17	465	14	44
7	209	......	12	48	......	41	39	14	17	278	13	27
8	185	......	13	44	......	37	36	34	15	141	18	25
9	128	25	23	43	......	37	39	56	96	82	13	50
10	98	25	16	36	......	36	57	44	96	81	11	52
11	83	25	13	34	......	36	60	......	62	58	11	39
12	63	22	6	30	......	36	57	......	197	48	13	28
13	56	23	......	30	......	39	72	......	458	43	43	22
14	50	27	......	30	......	41	72	......	267	35	30	14
15	41	26	......	27	......	41	57	......	128	28	47	34
16	37	24	......	24	......	37	46	60	89	34	51	122
17	36	25	......	38	......	35	41	50	134	31	89	......
18	......	41	......	47	63	34	42	62	156	52	183	......
19	......	46	......	56	83	35	38	120	96	50	145	......
20	......	30	......	56	127	39	40	112	82	135	175	......
21	......	24	......	52	95	39	42	68	206	114	102	......
22	......	23	......	46	74	39	......	50	118	72	71	......
23	......	17	......	55	60	39	......	39	101	52	50	......
24	......	14	......	51	62	37	......	34	278	43	38	......
25	......	14	......	158	72	35	......	24	195	36	30	......
26	......	10	......	211	62	31	......	20	109	38	26	......
27	......	10	......	205	55	29	......	37	68	41	24	......
28	......	10	......	......	55	29	18	56	68	35	23	......
29	......	......	......	......	49	27	16	92	56	36	24	46
30	......	......	......	......	43	25	15	101	46	104	19	39
31	......	......	......	......	40	......	15	86	......	50	......	145

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Day.	Jan.	Feb.	Mar.	Apr.	May.	June.
1920.							1920.						
1	227	......	25	21	58	75	16	35	205	38	......	225	......
2	221	......	24	21	57	78	17	35	211	30	......	166	......
3	143	......	19	20	57	89	18	34	150	28	......	146	......
4	89	......	20	20	66	101	19	......	92	28	......	101	......
5	117	......	20	23	60	96	20	......	65	25	......	75	......
6	258	......	20	23	46	90	21	......	58	23	......	65	......
7	570	0	20	22	44	81	22	......	54	20	......	60	......
8	342	146	20	21	41	75	23	......	51	19	......	56	......
9	175	112	19	21	37	79	24	......	44	18	......	55	......
10	120	146	22	23	35	75	25	......	43	18	......	55	......
11	78	175	38	42	39	60	26	......	38	18	89	56	......
12	56	137	42	28	48	55	27	......	34	20	107	65	......
13	56	128	32	......	50	44	28	......	30	25	83	68	......
14	50	109	32	......	51	......	29	......	28	25	72	72	......
15	40	109	27	......	89	......	30	......	......	23	65	72	......
							31	......	......	22	......	75	......

NOTE.—Discharge for following periods when gage did not operate satisfactorily estimated by comparison with records of Porcupine Creek near Nickel: Nov. 24–30, 1918, 87 second-feet; Jan. 18–31, 1919, 30 second-feet; Feb. 1–8, 27 second-feet; Mar. 13–19, 10 second-feet; Mar. 20–31, 28 second-feet; Apr. 1–3, 50 second-feet; Apr. 28–30, 125 second-feet, May 1–3, 65 second-feet; May 5–17, 55 second-feet; July 22–27, 30 second-feet; Aug. 11–15, 46 second-feet; Dec. 17–28, 77 second-feet; Apr. 13–25, 1920, 34 second-feet. Discharge for following periods estimated because stage-discharge relation was affected by ice: Feb. 10 and Feb. 27 to Mar. 4, 1919, Jan. 14, 15; Mar. 5–8, and Mar. 27 to Apr. 8, 1920, as shown in table; Jan. 19–31, 1920, 26 second-feet and Feb. 1–7, 86 second-feet.

Monthly discharge of Falls Creek at Nickel for the period May 6, 1918, to June 13, 1920.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.
1918.				
May 6-31	258	62	101	5,210
June	162	50	80.1	4,770
July	106	23	44.9	2,760
August	408	35	104	6,400
September	414	28	104	6,190
October	156	39	78.8	4,850
November	465	31	103	6,130
December	235	30	81.1	4,990
The period				41,300
1919.				
January	229		66.3	4,080
February		10	24.2	1,340
March		6	17.5	1,080
April	211	24	67.0	3,990
May	127		60.7	3,730
June	49	25	37.5	2,230
July	72	15	37.3	2,290
August	120	14	47.8	2,940
September	458	15	111	6,600
October	465	28	115	7,070
November	183	11	46.5	2,770
December		14	54.7	3,360
The year	465	6	57.3	41,500
1920.				
January	570		96.3	5,920
February		28	95.2	5,480
March	42	18	24.5	1,510
April	107		38.1	2,270
May	225	35	70.6	4,340
June 1-13	101	44	76.8	1,980
The period				21,500

PORCUPINE CREEK NEAR NICKEL.

LOCATION.—Half a mile above beach, on stream that enters tidewater at head of Porcupine Harbor, 4 miles northwest of camp of Alaska Nickel Mines Co., which is 20 miles by water northwest of Chichagof, on west coast of Chichagof Island.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—May 20, 1918, to August 22, 1920.

GAGE.—Stevens water-stage recorder on left bank of stream half a mile above beach.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from cable across stream 150 feet above gage; at low stages, made by wading near control.

CHANNEL AND CONTROL.—The gage is located at edge of deep pool formed by contraction of channel where stream passes over exposed bedrock and descends in a series of small falls. The head of these falls forms a well-defined and permanent control. At the cable section the bed is rough, the water is deep, and the current is sluggish and irregular, because 15 feet above cable the stream widens into a small lake.

EXTREMES OF DISCHARGE.—1918–1290: Maximum stage during period from water-stage recorder, 4.25 feet at 11 p. m. January 7, 1920 (discharge, from extension of rating curve, 1,180 second-feet); minimum stage, 0.37 foot March 19 and 28, 1919 (discharge, 24 second-feet).

ICE.—Stage-discharge relation not seriously affected by ice.

ACCURACY.—Stage-discharge relation practically permanent. Rating curve fairly well defined between 30 and 200 second-feet; extended beyond these limits. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights obtained by inspection of gage-height graph, or, for days of considerable fluctuation, by averaging discharge for intervals of the day. Records fair.

The following discharge measurement was made by G. H. Canfield:

June 13, 1920: Gage height, 1.24 feet; discharge, 84 second-feet.

Daily discharge, in second-feet, of Porcupine Creek near Nickel for the period May 21, 1918, to Aug. 31, 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918.												
1						191	130	73	185	157	191	
2						171	222	[illegible]	225	149	182	
3						157	236	[illegible]	193	143	140	
4						147	130	[illegible]	155	143	130	
5						130	113	65	135	133	365	
6						130	108	67	122	123	658	
7						130	104	73	109	124	465	
8						143	100	79	99	117	330	
9						147	96	76	93	110	240	
10						143	94	74	106	108	185	
11						143	98	71	101	95	161	
12						140	100	76	100	114	152	
13						123	95	94	94	122	137	
14						131	90	90	85	130	129	
15						129	88	90	82	127	120	
16						123	86	103	92	120	113	
17						118	83	103	126	120	104	
18						114	81	99	175	133	94	
19						109	78	103	175	129	85	
20						108	76	113	154	123	90	
21					93	105	73	133	136	117	96	
22					92	100	65	148	123	106	110	
23					90	98	60	187	129	100	110	
24					88	98	60	197	120	100	116	121
25					88	100	60	185	157	96	117	125
26					88	100	58	166	420	109	136	138
27					89	100	65	177	505	112	145	125
28					126	103	75	195	338	129	143	116
29					197	120	60	311	252	140	179	105
30					224	147	65	545	195	161	185	99
31					208		80	445		175		90
1919.												
1	88	52	32	43	112	92	75	65	126	145	104	
2	108	50	31	45	104	92	73	64	120	228	103	
3	109	48	31	47	98	94	73	62	109	499	104	
4	104	46	29	46	92	90	75	61	100	626	98	
5	110	44	28	50	89	88	75	62	93	635	98	
6	182	43	29	53	89	86	77	62	84	650	92	
7	195	42	29	53	90	84	81	52	80	500	86	
8	206	41	30	53	93	82	81	56	76	400	74	
9	197	41	33	53	95	80	82	67	94	355	81	
10	175	42	31	52	94	80	85	69	113	285	79	
11	159	41	30	52	92	79	96	69	103	222	73	
12	140	40	30	53	90	79	98	67	120	181	70	
13	126	39	29	53	89	78	105	76	445	155	77	
14	120	39	28	53	92	78	112	86	537	142	74	
15	109	39	26	52	99	79	110	84	362	132	79	
16	99	38	26	51	104	78	108	95	272	121	79	
17	92	36	26	53	101	78	104	92	252	113	93	
18	84	44	26	54	100	78	101	90	305	110	122	118
19	78	48	25	58	106	78	98	117	252	109	140	112
20	74	43	27	60	126	79	95	126	206	136	161	108
21	74	42	32	62	126	81	95	121	305	159	157	108
22	72	40	30	62	123	81	94	113	252	162	148	114
23	67	40	29	64	118	83	89	104	240	137	191	117
24	64	38	28	64	114	83	87	96	368	121		137
25	64	36	27	87	118	83	82	88	425	117		150
26	58	35	26	109	116	81	79	84	305	103		177
27	60	34	26	133	110	80	76	86	235	99		171
28	58	33	25	132	105	79	73	94	208	96		155
29	58		27	125	103	79	70	108	191	93		142
30	56		30	118	95	77	68	126	157	118		127
31	54		39		90		66	133		106		142

Daily discharge, in second-feet, of Porcupine Creek near Nickel for the period May 21, 1918, to Aug. 21, 1920—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1920.								
1	217	....	70	35	57	81	92	59
2	245	....	68	35	55	86	90	58
3	265	....	66	36	53	93	93	62
4	222	....	64	38	53	94	92	68
5	210	....	62	42	56	93	88	120
6	266	80	62	41	59	90	87	126
7	912	74	58	40	58	94	83	123
8	930	85	60	40	58	98	81	129
9	590	81	58	39	60	100	81	129
10	408	112	52	38	64	96	78	121
11	296	125	55	37	67	93	74	157
12	235	122	54	39	64	89	70	162
13	206	123	50	42	64	92	73	161
14	175	123	50	44	66	94	69	154
15	157	129	52	43	64	88	67	143
16	....	147	52	45	61	92	63	137
17	....	175	49	43	63	90	64	125
18	....	185	52	43	64	87	61	113
19	....	157	50	47	68	88	58	127
20	....	140	48	48	71	86	56	133
21	....	122	48	49	72	87	55	143
22	....	113	48	49	71	83	54	....
23	....	104	43	51	72	86	54	....
24	....	98	44	52	73	83	54	....
25	....	89	44	50	80	79	54	....
26	....	85	41	49	80	74	51	....
27	....	79	42	50	79	77	47	....
28	....	75	41	51	81	77	54	....
29	....	71	39	55	79	80	55	....
30	....	....	38	56	80	83	50	....
31	....	....	36	....	80	....	53	....

NOTE.—Discharge for following periods estimated because of unsatisfactory operation of water-stage recorder, by comparison with records of flow for near-by streams: July 22 to Aug. 4, 1918, as shown in table; Dec. 1–23, 135 second-feet; May 10–12, July 26–30, and Oct. 6–8, 1919, as shown in table; Nov. 24–30, 53 second-feet; Dec. 1–17, 71 second-feet; Jan. 16–31, 1920, 80 second-feet; discharge for following periods estimated because stage-discharge relation was affected by ice: Feb. 25 and Mar. 12, 1919, Mar. 1–6, and Mar. 28 to Apr. 4, 1920, as shown in table; Feb. 1–5, 1920, 50 second-feet.

Monthly discharge of Porcupine Creek near Nickel for the period May 21, 1918, to Aug. 21, 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1918.				
May 21–31	224	88	126	2,750
June	191	98	128	7,620
July	139	58	87.9	5,400
August	545	60	140	8,610
September	505	82	170	10,100
October	175	96	124	7,620
November	658	88	179	10,700
December	....	....	130	7,990
The period.	....	....	....	60,800
1919.				
January	206	54	104	6,400
February	52	33	41.2	2,290
March	39	25	28.9	1,780
April	133	43	66.3	3,950
May	126	89	102	6,270
June	94	77	82.0	4,880
July	112	66	86.5	5,320
August	133	52	86.3	5,310
September	537	76	218	13,000
October	650	93	228	14,000
November	....	....	91.8	5,460
December	....	....	99.5	6,120
The year.	650	25	103	74,800
1920.				
January	930	....	213	13,100
February	185	....	102	5,870
March	70	36	51.5	3,170
April	56	35	44.2	2,630
May	81	53	66.8	4,110
June	100	74	87.8	5,220
July	93	47	67.8	4,170
August 1–21	162	58	121	5,040
The period.	....	....	....	43,300

SWEETHEART FALLS CREEK NEAR SNETTISHAM.

LOCATION.—In latitude 57° 56½′ N., longitude 133° 41′ W., on east shore 1 mile from head of south arm of Port Snettisham, 3 miles south of mouth of Whiting River, 7 miles by water from Snettisham, and 42 miles by water from Juneau. No large tributaries enter river between gaging station and outlet of large lake, 2¼ miles upstream.

DRAINAGE AREA.—27 square miles (measured on United States Geological Survey topographic map of the Juneau gold belt, edition of 1905).

RECORDS AVAILABLE.—July 31, 1915, to March 31, 1917; May 21, 1918, to December 31, 1920.

GAGE.—Stevens water-stage recorder on right bank, 300 feet upstream from tidewater on east shore of Port Snettisham.

DISCHARGE MEASUREMENTS.—At medium and high stages, made from cable across river one-fourth mile upstream from gage; at low stages, made by wading in channel at mouth of creek exposed at low tide.

CHANNEL AND CONTROL.—From the outlet of the lake at an elevation of 520 feet above sea level and 2¼ miles from tidewater the water descends in a series of rapids and falls through a narrow, deep canyon. Gage is in a pool at foot of two falls, each 25 feet high, which are known as Sweetheart Falls; outlet of pool is a natural rock weir, which forms a well-defined and permanent control for gage.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 4.7 feet, at 10 a. m. August 6 (discharge computed from an extension of rating curve, 1,620 second-feet); minimum stage, 0.15 foot, April 10 (discharge, 28 second-feet).

1915–1920: Maximum stage recorded, 7.15 feet at midnight, September 26, 1918 (discharge computed from an extension of the rating curve, 2,880 second-feet); minimum discharge, estimated by current-meter measurement and climatic data, 15 second-feet, February 11, 1916.

ICE.—Stage-discharge affected by ice, April 5–7 and December 14–19.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 40 and 1,300 second-feet; extended beyond these limits by estimation. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table gage heights for regular intervals of day. Records excellent, except for period of break in record and for discharge above 1,300 second-feet, for which they are fair.

The only maps available, showing the lake and the drainage basin of this stream, are sheets 11 and 12 (scale 1:160,000) of the Alaska Boundary Tribunal, edition of 1895; topographic map of the Juneau gold belt (scale 1:250,000), United States Geological Survey, edition of 1905 (topography compiled from sheets of the Alaska Boundary Tribunal). From these maps, the following determinations have been made: Area of drainage basin above gaging station, 27 square miles, and above outlet of lake, 26 square miles; area of lake, 1,500 acres; distance from lake outlet to tidewater, 1¾ miles. The elevation of lake above high tide, measured by aneroid barometer, is 520 feet. An unpublished map of part of Port Snettisham (scale 1:31,680), made in 1920 by the United States Geological Survey in cooperation with the United States Forest Service, shows the topography, by a 100-foot contour interval, from the shore to a point about half a mile from outlet of lake.

The following discharge measurement was made by G. H. Canfield:

October 7, 1920: Gage height, 101 feet; discharge, 178 second-feet.

Daily discharge, in second-feet, of Sweetheart Falls Creek near Snettisham for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	159	58	47	....	133	565	865	470	805	765	785	79
2	249	58	44	....	137	645	805	442	685	505	1,150	72
3	428	58	43	....	144	705	685	432	645	418	1,040	67
4	351	74	41	....	146	785	605	470	765	321	705	67
5	264	113	40	37	144	845	625	846	665	255	505	64
6	240	121	47	35	135	845	645	1,530	505	206	685	58
7	628	119	53	34	131	765	665	1,350	765	166	545	57
8	1,040	102	44	32	121	725	705	1,240	1,190	183	407	53
9	725	96	39	29	115	685	745	845	945	505	312	49
10	470	92	40	28	113	665	765	565	645	470	243	46
11	348	125	42	37	125	605	725	922	435	365	196	42
12	258	108	53	52	183	565	705	1,330	330	300	155	40
13	202	90	52	50	199	545	665	1,330	261	276	129	39
14	183	78	48	44	191	545	625	1,080	210	249	113	38
15	152	79	44	41	210	585	625	745	183	219	106	38
16	131	88	40	39	318	605	625	505	164	183	96	38
17	....	146	41	38	318	565	585	400	148	155	85	38
18	....	109	38	38	340	565	545	330	137	131	80	38
19	....	178	36	38	309	505	525	324	152	117	74	38
20	....	150	33	37	273	452	505	340	150	148	79	37
21	....	123	32	37	249	424	470	418	137	228	80	36
22	....	98	....	37	249	585	452	435	129	231	78	33
23	....	85	....	36	261	605	418	365	123	382	76	30
24	....	73	....	37	279	505	372	306	111	414	74	29
25	....	67	....	47	282	460	348	255	113	321	72	29
26	....	60	....	85	282	505	358	300	98	288	72	30
27	....	57	....	119	297	565	386	585	90	625	64	82
28	....	54	....	131	334	625	386	505	159	625	73	127
29	....	50	....	135	386	745	882	393	682	452	88	90
30	....	....	....	133	452	865	382	315	1,120	545	88	70
31	....	....	....	....	505	....	418	452	....	777	....	90

NOTE.—Discharge for following periods estimated, because of ice or unsatisfactory operation of water-stage recorder, by comparison with climatic data for Juneau and hydrographs for streams in near-by drainage basins: Jan. 17–31, 80 second-feet; Mar. 22–31, 32 second-feet; Apr. 1–4, 30 second-feet; Feb. 1, 2, Apr. 5–7, Dec. 14–19, and Dec. 29–31, daily discharge.

Monthly discharge of Sweetheart Falls Creek near Snettisham, for 1920.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.	Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.
January	1,040	....	227	14,000	August	1,530	255	640	39,400
February	178	50	93.4	5,370	September	1,190	90	418	24,900
March	53	....	39.3	2,420	October	777	117	349	21,500
April	135	28	50.9	3,030	November	1,150	64	275	16,400
May	505	113	237	14,600	December	127	29	53.0	3,260
June	865	424	622	37,000					
July	865	348	568	34,900	The year	1,530	28	298	217,000

CRATER LAKE OUTLET AT SPEEL RIVER, PORT SNETTISHAM.

LOCATION.—At outlet of Crater Lake, 1 mile upstream from edge of tide flats at head of north arm of Port Snettisham, 2 miles by trail from cabins of Speel River project, which are 42 miles by water from Juneau.

DRAINAGE AREA.—11.9 square miles above water-stage recorder at lake outlet, and 13 square miles above staff gage at beach (measured on topographic maps of the Alaska Boundary Tribunal, edition of 1895).

RECORDS AVAILABLE.—January 23, 1913, to December 31, 1920.

GAGE.—Stevens water-stage recorder on left shore of lake 100 feet upstream from outlet. A locally made water-stage recorder having a natural vertical scale and a time scale of 7 inches to 24 hours was used until replaced by Stevens gage June 29, 1916. The gage datum remained the same during the period. During the winter, because of inaccessible location and deep snow, the operation of the gage at the lake was discontinued, and the stage read at staff gage in channel exposed at low tide at beach. The first gage at beach was set at an unknown datum and washed out in winter of 1915–16. Another staff gage was set at about the same location November 24, 1916. Other staff gages were set at about the same location January 11 and November 13, 1918.

DISCHARGE MEASUREMENTS.—Made from cable across outlet of lake, 100 feet downstream from gage and 10 feet upstream from crest of first falls. The rope sling from which discharge measurements were first made was replaced in fall of 1915 by a standard United States Geological Survey gaging car, making more reliable measurements possible.

CHANNEL AND CONTROL.—The gage is on left shore of lake, 100 feet upstream from outlet, where the stream becomes constricted into a narrow channel, the bed of which is composed of large boulders and rock outcrops that form a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during the year, 6.75 feet at 2 a. m. August 6 (discharge computed from an extension of rating curve, 2,100 second-feet); minimum discharge, estimated, 10 second-feet about March 31.

1913–1920: Maximum stage occurred probably on September 26, 1918 (discharge estimated at 2,300 second-feet by multiplying maximum discharge at Long River on September 27, 1918, by 0.44, which is the ratio between the maximum discharges of Crater Lake outlet and Long River on August 19 and 20, 1917); minimum discharge, 5.0 second-feet, February 4, 1916, and February 13, 1919.

ACCURACY.—Stage-discharge relation permanent. Rating curve well-defined below and extended above 1,000 second-feet. Operation of water-stage recorder satisfactory except for periods indicated by breaks in record as shown in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table daily gage height determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day.

Crater Lake is 1,010 feet above sea level and covers 1.1 square miles. The sides of the mountains surrounding the lake are steep and barren, and the tops are covered by glaciers.

Discharge measurements of Crater Lake outlet at Port Snettisham during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Feb. 4		[a] 12	May 14	0.26	[b] 52
Apr. 6		[b] 11.5	Nov. 11	.48	[b] 52

[a] Estimated discharge at beach.
[b] Estimated inflow between the outlet of Crater Lake and the beach subtracted from the discharge measured at the beach.

Daily discharge, in second-feet, of Crater Lake outlet at Speel River, Port Snettisham, for the period Oct. 1919, to Nov. 11, 1920.

Day.	Oct.	Nov.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	......	50	......	95	532	517	251	350	251
2	......	43	......	103	416	416	327	212	402
3	......	33	......	108	327	362	532	171	350
4	......	34	......	114	304	443	594	125	221
5	......	......	......	118	338	1,440	375	93	153
6	......	......	......	121	388	1,720	350	74	241
7	......	......	......	122	429	1,230	675	62	186
8	......	......	......	125	472	610	798	151	126
9	282	......	......	126	502	402	798	304	98
10	194	......	......	127	502	304	280	217	78
11	139	......	......	130	502	1,060	186	150	62
12	116	......	......	131	472	1,090	138	120	......
13	98	......	......	132	443	762	115	108	......
14	82	......	......	134	443	502	101	94	......
15	70	......	......	135	443	338	95	78	......
16	63	......	......	136	472	259	98	64	......
17	62	56	......	138	443	221	90	52	......
18	67	194	......	140	402	219	98	43	......
19	100	241	......	142	402	302	142	40	......
20	246	221	......	143	388	375	122	55	......
21	338	251	......	146	388	532	100	78	......
22	203	161	......	146	375	429	89	79	......
23	132	108	64	161	327	304	81	122	......
24	98	78	66	180	293	221	74	126	......
25	78	60	68	198	293	178	67	98	......
26	66	49	68	241	327	287	61	108	......
27	63	......	70	304	362	762	54	327	......
28	62	......	75	362	362	472	79	251	......
29	55	......	78	472	375	282	472	158	......
30	55	......	84	594	388	208	626	203	......
31	52	......	90	......	472	223	......	231	......

NOTE.—Discharge for following periods estimated, because of ice or unsatisfactory operation of water-stage recorder, by comparison with hydrograph and record of flow for Sweetheart Falls Creek: Oct. 1–8, 1919, 470 second-feet; Nov. 5–16, 22 second-feet; Nov. 27–30, 40 second-feet; Dec. 1–31, 45 second-feet; Jan. 1–31, 1920, 100 second-feet; Feb. 1–29, 35 second-feet; Mar. 1–31, 16 second-feet; Apr. 30, 20 second-feet; and May 1–22, 45 second-feet; June 24 and Aug. 6–10, daily discharge. Figures for October, November, and December, 1919, supersede those published in previous report.

Monthly discharge of Crater Lake outlet at Speel River, Port Snettisham, for the period Oct. 1, 1919, to Nov. 11, 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
1919.									
October	......	52	209	12,900	April	......	......	20	1,190
November	251	......	67	3,990	May	......	......	53.4	3,280
December	......	......	45	2,770	June	594	95	177	10,500
					July	532	293	406	25,000
The period	......	......	107	19,700	August	1,720	178	532	32,700
					September	798	54	262	15,600
1920.					October	350	40	140	8,610
January	......	......	100	6,150	November 1-11	402	62	197	4,300
February	......	......	35	2,010					
March	......	......	16	984	The period	......	......	......	110,000

NOTE.—Figures for October, November, and December, 1919, supersede those published in previous report.

LONG RIVER BELOW SECOND LAKE, AT PORT SNETTISHAM.

LOCATION.—Half a mile downstream from outlet of Second Lake, 1 mile downstream from outlet of Long Lake, half a mile upstream from head of Indian Lake; 2½ miles by trail and boat across Second Lake from cabins of the Speel River project at head of the North Arm of Port Snettisham, 45 miles by water from Juneau.

DRAINAGE AREA.—33.2 square miles (measured on sheet No. 12 of the Alaska Boundary Tribunal maps, edition of 1895).

RECORDS AVAILABLE.—November 11, 1915, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on right bank half a mile below outlet of Second Lake.

DISCHARGE MEASUREMENTS.—At medium and high stages made from cable across river at gage; at low stages made by wading one-fourth mile downstream.

CHANNEL AND CONTROL.—At the gage the channel is deep and the current sluggish; banks are low and are overflowed at extremely high stages; bed smooth except for one large boulder. A rapid, 500 feet downstream, forms a well-defined and permanent control.

EXTREMES OF DISCHARGE.—Maximum stage during year, 9.2 feet at about 5 a. m. August 6 (discharge, estimated from extension of rating curve, 4,300 second-feet); minimum discharge, estimated, 30 second-feet, April 9–10. 1916–1920: Maximum stage, 10.2 feet September 27, 1918 (discharge, estimated from extension of rating curve, 5,300 second-feet); minimum discharge, 23 second-feet, February 13, 1916.

ICE.—Stage-discharge relation affected by ice during January, February, March, April, and December.

ACCURACY.—Stage-discharge relation permanent; affected by ice or poor connection between well and river January 1 to February 8, March 23 to May 15, and November 29 to December 31. Rating curve fairly well defined between 50 and 400 second-feet and well defined between 400 and 2,000 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily discharge table. Daily discharge ascertained by applying to the rating table daily gage heights determined by inspecting the gage-height graph. Records good, except for stages below 400 second-feet and for periods of break in record, for which they are fair.

Long Lake is at an elevation of 803 feet above sea level, is 2,000 acres in area, and is about 2 miles, by line of possible water conduit, from tidewater at cabins of the Speel River project.

The area of the drainage basin above the outlet of Long Lake is 31.9 square miles. The area draining to Long River between the outlet of Long Lake and this station comprises only 1.3 square miles, including First Lake and Second Lake. Because this area is at a low altitude and has no glaciers the run-off per square mile from it is greater early in the spring but much less in summer than that from the area above Long Lake, which is partly covered by glaciers.

Discharge measurements of Long River below Second Lake, at Port Snettisham, during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
Apr. 6	[a] 0.84	38	Nov. 11	1.71	181
May 13		140			

[a] River partly frozen over at control.

Daily discharge, in second-feet, of Long River below Second Lake, at Port Snettisham, for 1920.

Day.	Feb.	Mar.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	50	51	....	465	900	998	740	1,040	620
2	50	50	....	512	800	930	840	740	1,190
3	55	49	....	582	750	840	1,160	582	952
4	60	48	....	620	700	908	1,310	426	600
5	100	48	....	680	760	2,360	998	330	468
6	160	48	....	680	820	3,760	885	239	582
7	130	46	....	640	908	2,340	1,490	194	487
8	110	45	....	600	1,020	1,510	1,690	337	357
9	93	44	....	600	1,060	1,090	1,240	565	264
10	108	42	....	600	1,110	885	840	468	202
11	180	45	....	582	1,110	1,900	600	375	173
12	120	50	....	565	1,110	2,480	468	339	157
13	89	54	....	530	1,060	1,780	387	341	138
14	81	50	....	530	1,060	1,310	339	293	123
15	82	50	....	548	1,060	975	301	239	113
16	95	48	390	565	1,090	780	331	181	105
17	204	47	325	548	1,040	660	295	149	101
18	204	46	354	600	998	620	351	130	98
19	134	49	312	565	975	740	402	117	86
20	98	45	295	523	952	840	314	220	94
21	77	45	298	471	930	1,130	262	357	95
22	68	45	339	600	908	1,020	234	312	94
23	63	....	341	548	820	800	211	435	92
24	62	....	325	465	740	640	190	282	91
25	58	....	301	426	700	530	177	220	89
26	56	....	298	465	760	756	166	259	88
27	54	....	325	530	820	1,380	152	620	87
28	53	....	334	800	820	1,110	306	548	89
29	52	....	354	750	862	800	1,090	414	110
30	....	....	390	800	885	620	1,460	540	110
31	....	....	420	....	930	660	....	523	....

NOTE.—Discharge estimated for following periods, because stage-discharge relation was affected by ice or obstructed connection between well and river, or because of unsatisfactory operation of water-stage recorder, by comparison with climatic data at Juneau and by hydrographs and records of flow for streams in near-by drainage basins: Jan. 1-31, 180 second-feet; Feb. 1-8, daily discharge; Mar. 23-31, 41 second-feet; Apr. 1-30, 52 second-feet; May 1-15, 125 second-feet; June 28 to July 3, Oct. 5, Nov. 29 and 30, daily discharge; Dec. 1-31, 60 second-feet.

Monthly discharge of Long River below Second Lake, at Port Snettisham, for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	....	....	180	11,100	August	3,760	530	1,200	73,800
February	204	50	94.7	5,450	September	1,690	152	641	38,100
March	51	....	45.6	2,800	October	1,040	117	381	23,400
April	....	....	52	3,090	November	1,190	86	262	15,600
May	420	....	235	14,400	December	....	....	60	3,690
June	800	426	580	34,500					
July	1,110	700	918	56,400	The year	3,760	....	389	282,000

GRINDSTONE CREEK AT TAKU INLET.

LOCATION.—On north shore of Taku Inlet, between Point Bishop and Point Salisbury, one-fourth mile west of mouth of Rhine Creek and 11 miles by water from Juneau.

DRAINAGE AREA.—3.6 square miles (measured on general map of vicinity of Juneau prepared by Alaska Gastineau Mining Co., edition of 1916).

RECORDS AVAILABLE.—May 6, 1916, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on left bank, 200 feet from tidewater, installed September 16, 1916. A Lietz seven-day graph water-stage recorder was used May 6 to June 17, 1916.

DISCHARGE MEASUREMENTS.—At all stages made by wading either in the channel on the beach, which is exposed at low tide, or 100 feet below gage at high tide.

CHANNEL AND CONTROL.—For a distance of one-fourth mile from tidewater the stream descends in a series of rapids and falls through a narrow, rocky channel. The gage is at upper end of a turbulent pool between two falls, the lower of which forms a well-defined control. When gage was installed, logs were jammed in channel near upper end of pool.

EXTREMES OF DISCHARGE.—Maximum stage during year from water-stage recorder, 3.4 feet at 4 a. m., August 6 (discharge, from extension of rating curve, 317 second-feet); minimum discharge estimated by comparison with hydrographs for streams in near-by drainage basins, 3.5 second-feet, April 6, December 24 and 25.

1916–1920: Maximum stage, 6 feet at 7 p. m. September 26, 1918 (discharge, estimated from an extension of the rating curve, 700 second-feet); minimum stage, −0.24 foot April 5–7, 1918 (discharge, 2.6 second-feet).

ICE.—Stage-discharge relation sometimes affected by ice.

ACCURACY.—Stage-discharge relation permanent. Rating curve fairly well defined below 150 second-feet; extended above 150 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods shown in the footnote to daily-discharge table. Discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of day. Records fair, except those for periods of break in record and discharge above 150 second-feet, which are poor.

Discharge measurements of Grindstone Creek at Taku Inlet during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Apr. 5	−0.04	3.9	Oct. 4	0.74	28
July 10	1.17	55	Nov. 10	.81	30
Aug. 24	1.23	64			

Daily discharge, in second-feet, of Grindstone Creek at Taku Inlet for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	17	6	7.5	4.4	21	67	120	48	24	35	63	13
2	24	5	7.0	4.2	24	84	92	34	24	30	66	12
3	22	5	6.3	4.1	24	97	77	38	32	25	57	12
4	17	8	7.8	4.0	20	91	72	43	24	22	47	12
5	16	12	7.9	3.9	19	102	72	174	24	21	42	12
6	21	15	8.0	3.5	18	92	72	168	40	19	48	11
7	83	14	8.0	3.6	18	80	72	80	73	18	40	11
8	49	11	8.0	3.7	16	77	72	55	81	21	33	10
9	26	11	6.9	3.7	16	77	70	45	52	29	31	8.4
10	21	12	6.8	3.7	17	75	67	41	43	26	27	......
11	18	15	7.2	7.5	21	72	60	102	36	24	24	......
12	......	11	7.2	12	25	72	59	65	31	22	22	......
13	......	10	6.4	8.1	35	68	50	55	26	24	20	......
14	......	12	6.3	6.2	35	70	49	46	24	29	19	......
15	......	13	5.9	5.8	45	77	48	41	22	24	19	......
16	......	20	5.9	5.7	60	77	45	37	24	22	17	......
17	......	32	5.8	5.4	50	74	45	32	21	19	17	......
18	......	24	5.8	6.0	40	77	42	39	24	18	16	......
19	......	16	5.6	7.2	32	66	38	60	24	17	16	......
20	......	14	5.4	7.5	26	57	34	48	21	21	16	......
21	......	12	5.4	7.8	26	55	32	67	20	21	16	......
22	......	11	5.1	7.8	34	74	30	44	19	23	15	......
23	......	10	5.1	8.4	36	72	26	38	19	24	14	......
24	......	9.0	4.8	9.2	36	61	24	32	19	22	14	......
25	......	9.0	4.8	16	37	55	26	29	18	20	14	......
26	......	8.7	5.2	45	41	82	26	38	17	28	14	......
27	......	8.4	5.0	62	49	92	30	39	16	49	13	......
28	......	8.2	5.0	34	55	88	30	31	40	35	15	......
29	......	8.2	4.6	25	62	133	28	26	60	30	15	......
30	......	......	4.5	20	68	186	26	24	45	61	13	......
31	......	......	4.5	......	72	......	60	25	......	49	......	......

NOTE.—Discharge estimated for following periods, because stage-discharge relation was affected by ice or water-stage recorder was not operating: Jan. 12–31 (10 second-feet), Feb. 1–5, Mar. 4–8, and Mar. 30 to Apr. 10, by comparison with hydrographs of streams in near-by drainage basins and climatic data for Juneau; May 12–18, from maximum and minimum stages indicated by recorder and comparison with record of flow for Sheep Creek; Aug. 16–20, from gage-height graph drawn by comparison with that for Sheep Creek; Sept. 27 to Oct. 3 (daily discharge) and Dec. 10–31 (6.3 second-feet), from maximum and minimum stages indicated by recorder and comparison with records of flow for Sheep Creek and Sweetheart Falls.

Monthly discharge of Grindstone Creek at Taku Inlet for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	83	......	16.6	1,020	August	174	24	53.0	3,260
February	32	5.0	12.1	696	September	81	16	31.4	1,870
March	8.0	4.5	6.12	376	October	61	17	26.7	1,640
April	62	3.5	11.5	684	November	66	13	26.1	1,550
May	72	16	34.8	2,140	December	13	......	7.74	476
June	186	55	81.7	4,860					
July	120	24	51.4	3,160	The year	186	3.5	29.9	21,700

CARLSON CREEK AT SUNNY COVE, TAKU INLET.

LOCATION.—At Sunny Cove, on west shore of Taku Inlet, 20 miles by water from Juneau.

DRAINAGE AREA.—22.26 square miles (determined by engineering department of Alaska Gastineau Mining Co. from surveys made by that company).

RECORDS AVAILABLE.—July 18, 1916, to December 31, 1920.

GAGE.—Stevens water-stage recorder on left bank, 2 miles from tidewater.

DISCHARGE MEASUREMENTS.—At high stages, made from cable across river half a mile downstream from gage; at medium and low stages, made by wading 500 feet upstream from gage.

CHANNEL AND CONTROL.—Above the gage the stream meanders in one main channel and several small channels through a flat, sandy basin about a mile long; just below the gage the channel contracts and the stream passes over rocky falls that form a well-defined and permanent control. The point of zero flow is at gage height −1.5 feet.

EXTREMES OF DISCHARGE.—Maximum stage during year, 7.15 feet at 8 p. m. August 5 (discharge computed from extension of rating curve, 4,950 second-feet); minimum flow, estimated, 12 second-feet, April 3.

1916–1920: Maximum stage, 8.1 feet at 2 p. m. September 26, 1918 (discharge, computed from extension of rating curve, 6,200 second-feet); minimum flow, estimated from climatic data and hydrographs for streams in near-by drainage basins, 10 second-feet, April 1–7, 1918.

ICE.—Stage-discharge relation affected by ice January 1 to about May 1.

ACCURACY.—Stage-discharge relation permanent. Rating curve well defined between 70 and 2,000 second-feet, extended below 70 second-feet to point of zero flow and above 2,000 second-feet by estimation. Operation of water-stage recorder satisfactory except for periods of break in record as indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging results obtained by applying to rating table mean gage heights for regular intervals of the day. Records good, except for stages below 70 second-feet and above 2,000 second-feet, and for periods of break in record, for which they are fair.

A possible site for a dam is about 2 miles from tidewater at the outlet of a flat gravel basin. The elevation of the stream bed at this point is 350 feet above high tide. A dam 120 feet high would form a reservoir having a storage capacity of 30,000 acre-feet, which is less than half the capacity required to equalize the annual run-off.

Discharge measurements of Carlson Creek at Sunny Cove during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Feb. 6		[a] 49	May 29	1.46	[a] 425
Apr. 7		[a] 15	Nov. 10	.08	130

[a] Creek frozen over. Measurement made 2 miles below gage, and measured discharge reduced 5 per cent in order to give flow at gage.

Daily discharge, in second-feet, of Carlson Creek at Sunny Cove for 1920.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	....	882	640	318	308	390	16	....	780	320	164	117	....
2	....	675	470	500	250	1,000	17	....	675	328	124	98	....
3	....	590	455	975	258	545	18	820	658	367	164	122	....
4	....	658	561	658	172	265	19	658	640	590	234	108	....
5	....	762	3,950	425	124	196	20	560	605	515	164	176	....
6	....	800	2,090	545	108	396	21	485	605	742	144	214	....
7	....	882	745	1,690	102	300	22	692	575	390	124	212	....
8	....	928	545	1,180	337	230	23	545	485	285	117	396	....
9	....	928	396	485	812	175	24	461	455	234	117	265	....
10	....	905	354	302	308	124	25	515	470	210	118	172	....
11	....	860	2,440	243	227	108	26	762	545	586	118	410	....
12	....	800	905	196	227	102	27	820	560	1,360	119	710	....
13	....	762	710	167	247	....	28	840	545	560	714	396	....
14	....	762	545	172	191	....	29	1,080	545	338	1,440	223	....
15	....	745	396	188	144	....	30	1,080	530	270	515	455	....
							31	....	675	421	....	340	....

NOTE.—Discharge estimated for following periods from current-meter measurements and by comparison with records of flow for Sweetheart Falls Creek, because stage-discharge relation was affected by ice or water-stage recorder was not operating: Jan. 1-31, 110 second-feet; Feb. 1-28, 42 second-feet; Mar. 1-31, 18 second-feet; Apr. 1-30, 25 second-feet; May 1-31, 240 second-feet; June 1-17, 730 second-feet; Nov. 6-9, as shown in table; Nov. 13-30, 55 second-feet; and Dec. 1-31, 33 second-feet.

Monthly discharge of Carlson Creek at Sunny Cove for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	....	....	110	6,760	August	3,950	210	733	45,100
February	....	....	42	2,420	September	1,690	117	414	24,600
March	....	....	18	1,110	October	812	98	265	16,300
April	....	....	25	1,490	November	1,000	....	161	9,580
May	....	....	240	14,800	December	....	....	33	2,030
June	1,080	....	724	43,100					
July	928	455	687	42,200	The year	3,950	....	289	209,000

SHEEP CREEK NEAR THANE.

Location.—At lower end of flat basin, above diversion dam for flume leading to Treadwell power house at beach and 1 mile by tramway and ore railway from Thane.

Drainage area.—4.57 square miles above gaging bridge (measured on United States Geological Survey map of Juneau and vicinity, edition of 1917).

Records available.—July 26, 1916, to December 31, 1920.

Gage.—Stevens water-stage recorder on right bank, at pool formed by an artificial control just below small island three-tenths mile upstream from diversion dam. Recorder inspected by an employee of the Alaska Gastineau Mining Co.

Discharge measurements.—At extremely high stages, made from gaging bridge two-tenths mile downstream from gage; at low stages, made by wading near bridge section. No streams enter between gage and measuring section, but seepage inflow ranges from a small amount to 10 per cent of total flow, the percentage of inflow usually being large after periods of heavy precipitation.

Channel and control.—The station is near the lower end of a flat basin through which the stream meanders in a channel having low banks and a bed of sand and gravel. An artificial control was built 2 feet below the intake for the gage well, to confine the flow in one channel during high water and to insure a permanent stage-discharge relation. The spillway of the control at low stages consists of a timber, 16 feet long, set in the bed of the stream. During medium and high stages another timber, 8 feet long, bolted at the top near the right end, forms part of the control. A 3-foot cut-off wall is driven at the upstream face of the spillway. There are wing walls at each end, and an 8-foot apron extends downstream from the control.

Ice.—Control covered with ice and snow for short period. Flow passes through gravel bed under and around weir and enters creek again above gaging section one-fourth mile downstream.

Extremes of discharge.—Maximum stage during year, 2.41 feet at 12.30 a. m. August 6 (discharge, 458 second-feet); minimum stage, −0.35 foot, on April 13 and 14 (discharge, 5.6 second-feet).

1916–1920: Maximum stage during period, 3.5 feet, at 2 p. m. September 26, 1918 (discharge, estimated from extension of rating curve, 820 second-feet); minimum flow, 1.0 second-foot, April 6–8, 1917.

Accuracy.—Stage-discharge relation below 1.2 feet changed January 6 because of shifting of gravel bed above the artificial control. Rating curves used January 1–6 and January 7 to December 31 fairly well defined below 700 second-feet.

Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily-discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuation, by averaging discharges obtained by applying to rating table mean gage heights for regular intervals of the day. Records fair.

Discharge measurements of Sheep Creek near Thane during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 31	0.44	13	Aug. 9	0.96	66
Mar. 27	.07	7.6	Sept. 27	.64	23
Apr. 15	−.32	[a] 5.7	Oct. 25	.80	39
June 10	1.15	103	Nov. 23	.55	18

[a] Discharge at gaging section at bridge, two-tenths mile downstream from weir; no flow at weir section.

Daily discharge, in second-feet, of Sheep Creek near Thane for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	30	13	....	6.8	22	108	151	84	47	50	113	16
2	50	13	....	6.7	25	121	121	61	53	45	134	16
3	40	13	....	6.6	25	144	108	58	77	45	101	15
4	30	13	....	6.5	25	146	108	72	61	35	82	14
5	22	13	....	6.4	24	151	108	238	53	32	74	14
6	30	13	....	6.2	22	138	108	226	77	28	121	13
7	175	14	....	6.1	22	126	108	115	151	26	82	13
8	108	15	....	6.0	20	121	113	86	136	53	68	13
9	72	15	....	5.9	22	113	108	68	96	96	60	12
10	53	15	....	5.8	25	108	100	70	77	56	50	12
11	44	16	....	5.8	35	108	96	216	63	51	41	12
12	34	15	11	5.7	39	108	92	115	54	50	36	12
13	29	15	10	5.7	41	103	88	91	47	50	30	12
14	25	15	9.8	5.6	39	105	84	77	43	48	28	12
15	25	14	9.6	5.7	53	115	88	61	43	41	28	11
16	23	15	9.3	5.8	74	113	82	53	39	39	25	11
17	22	16	9.1	5.9	63	108	79	48	39	33	24	10
18	20	19	9.1	6.1	68	126	77	53	45	30	22	10
19	19	19	8.9	6.2	56	101	70	82	45	29	22	11
20	18	19	8.8	6.2	47	88	70	72	39	41	22	11
21	18	19	8.7	6.4	45	84	70	101	34	39	21	10
22	17	18	8.5	6.6	48	98	61	60	30	43	19	10
23	17	18	8.4	6.8	48	86	58	50	28	53	18	10
24	16	17	8.2	7.2	54	77	53	44	26	43	18	9
25	16	17	8.0	7.7	56	79	53	43	24	39	17	9
26	15	16	8.0	8.6	56	115	56	72	24	84	17	8
27	15	16	7.7	11	63	118	61	74	23	101	17	9
28	14	15	7.5	14	77	126	61	63	56	72	17	9
29	14	14	7.3	19	86	166	61	53	77	60	17	9
30	14	....	7.2	22	96	192	58	48	60	121	16	10
31	13	....	6.9	....	101	....	98	51	....	84	....	10

NOTE.—Water-stage recorder not operating for following periods; discharge estimated by comparison with hydrographs and records of flow for streams in near-by drainage basins: Jan. 1-7, Jan. 18-30, and Feb. 22-29, as shown in table; Mar. 1-11, 112 second-feet; May 8-11, July 9-13, Sept. 18-26, and Dec. 17-31, as shown in table.

Monthly discharge of Sheep Creek near Thane for 1920.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.	Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off in acre-feet.
January	175	13	33.5	2,060	August	238	43	84.0	5,160
February	19	13	15.5	892	September	151	23	55.6	3,310
March	....	6.9	9.81	603	October	121	26	52.2	3,210
April	22	5.6	7.70	458	November	134	16	44.7	2,660
May	101	20	47.6	2,930	December	16	8	11.4	701
June	192	77	116	6,900					
July	151	53	85.5	5,260	The year	238	5.6	47.1	34,100

GOLD CREEK AT JUNEAU.

LOCATION.—At highway bridge at lower end of Last Chance basin, 200 feet upstream from diversion dam of Alaska Electric Light & Power Co. and one-fourth mile from Juneau.

DRAINAGE AREA.—9.47 square miles (determined by engineering department of Alaska Gastineau Mining Co. from surveys made by that company.

RECORDS AVAILABLE.—July 20, 1916, to December 31, 1920.

GAGE.—Stevens continuous water-stage recorder on left bank at upstream side of highway bridge.

DISCHARGE MEASUREMENTS.—At medium and high stages made from gaging bridge suspended, at right angles to current, from floor of highway bridge; at low stages made by wading near gage.

CHANNEL AND CONTROL.—Station is at lower end of a flat gravel basin three-fourths mile long. For 20 feet upstream from gage the stream is confined between the abutments of an old bridge and for 15 feet downstream it is confined between the abutments of present bridge. For a distance of 130 feet farther downstream the stream is confined in a narrow channel which is not subject to overflow. Because of the steep gradient of channel opposite and for 150 feet below gage, a short stretch of the channel immediately below the gage acts as the control. The operation of the headgates of flume at diversion dam, 200 feet downstream, does not affect the stage-discharge relation at gage, but the swift current during high stages shifts the gravel in bed of stream, thereby causing changes in the stage-discharge relation.

EXTREMES OF DISCHARGE.—Maximum stage during year, 5.0 feet August 5 (discharge estimated from extension of rating curve, 1,600 second-feet); minimum discharge, 1.5 second-feet April 10.

1916–1920: Maximum stage, 6.8 feet September 26, 1918 (discharge estimated from extension of rating curve, 2,600 second-feet); minimum discharge, 0.9 second-foot March 26, 1918.

ICE.—Stage-discharge relation affected by ice January 13 and March 30.

DIVERSION.—Water diverted at several points upstream for the development of power is returned to creek above gage, except about 20 second-feet for seven months (when there is a surplus over amount used by Alaska Electric Light & Power Co., which has prior right) and 1 second-foot the remainder of year, used by the Alaska-Juneau Gold Mining Co. A dam 200 feet downstream diverts water into the flume of the Alaska Electric Light & Power Co.

REGULATION.—No storage or diversions above station regulate the flow more than a few hours in low water.

ACCURACY.—Stage-discharge relation changed during periods of high water; 11 discharge measurements made during year, by use of which rating curves have been constructed applicable as follows: January 1–7, poorly defined; January 8 to Aug. 5, August 6 to September 27, September 28 to November 1, and November 2 to December 31, fairly well defined below and poorly defined above 200 second-feet. Operation of water-stage recorder satisfactory except for periods indicated in footnote to daily discharge table. Daily discharge ascertained by applying to rating table mean daily gage heights determined by inspecting gage-height graph, or, for days of considerable fluctuations, by averaging discharges obtained by applying to rating table mean gage heights for equal intervals of the day. Records fair.

Discharge measurements of Gold Creek at Juneau during 1920.

[Made by G. H. Canfield.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
Jan. 19	0.79	19.	June 25	1.77	166
30 [a]	.68	9.8	Aug. 16	1.95	101
Mar. 26	.47	2.3	Sept. 27	1.44	28
Apr. 10	.40	1.5	Oct. 29	1.96	77
30	.91	30	Dec. 20	.96	7.8
May 27	1.33	83			

[a] Control and measuring section frozen over.

Daily discharge, in second-feet, of Gold Creek at Juneau for 1920.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	45	9	7.0	1.8	36	171	343	301	143	92	205	19
2	74	9	6.1	1.7	37	198	270	173	220	78	480	17
3	69	9	5.8	1.7	35	245	234	162	362	83	305	19
4	41	9	5.6	1.7	33	263	254	225	295	53	196	19
5	33	10	5.4	1.6	29	279	285	1,000	178	46	190	17
6	43	14	5.2	1.6	28	263	307	620	220	39	381	17
7	434	21	5.0	1.6	26	220	334	280	552	36	222	16
8	162	17	4.8	1.5	25	217	350	206	510	83	160	15
9	82	15	4.8	1.5	26	220	334	220	265	262	126	14
10	62	17	4.8	1.5	33	225	317	168	168	114	102	12
11	48	19	5.2	5.0	52	212	291	880	137	83	79	11
12	38	18	5.7	20	55	212	276	432	116	75	65	10
13	......	12	4.8	15	50	198	263	180	105	75	58	10
14	......	11	4.8	10	61	219	254	127	94	67	58	8.5
15	......	11	3.0	8.0	90	248	270	108	91	56	56	7.0
16	......	19	3.4	7.0	75	270	260	108	96	44	46	7.5
17	......	30	3.9	6.0	91	245	240	96	75	36	44	8.0
18	......	32	3.0	5.7	69	317	237	131	75	30	43	10
19	19	19	3.0	5.7	58	248	225	274	98	29	42	10
20	......	19	3.0	6.2	56	203	219	192	75	42	39	10
21	......	15	2.7	6.2	62	180	225	295	68	63	37	9.5
22	......	14	2.7	5.7	65	225	212	143	61	48	33	8.0
23	......	12	2.7	6.2	72	196	183	98	44	88	30	6.0
24	......	11	2.4	8.6	76	164	169	78	41	78	29	5.6
25	......	10	2.4	19	76	178	178	72	38	61	28	6.0
26	......	9.2	2.5	31	80	301	206	192	35	198	25	6.0
27	......	8.6	2.5	33	91	317	214	378	30	262	23	7.5
28	......	8.6	2.5	33	105	327	219	214	185	122	33	8.5
29	......	8.6	2.5	30	121	413	219	147	325	83	29	8.5
30	9.8	......	2.1	33	136	480	206	127	137	219	25	8.5
31	9.0	......	1.9	......	149	......	334	173	......	137	......	8.5

NOTE.—Discharge estimated from discharge measurements, climatic data at Juneau, and by comparison with hydrographs for streams in near-by drainage basins for following periods, because of unsatisfactory operation of water-stage recorder: Jan. 13–18, 28 second-feet; Jan. 20–29, 14 second-feet; Jan. 30, Feb. 1–6, Mar. 3–7, Mar. 30–31, Apr. 1–9, and Apr. 11–17, as shown in table. Discharge, May 26, interpolated; Aug. 1–12 and Oct. 23–25, determined from gage-height graph drawn by comparison with that for Carlson Creek.

Monthly discharge of Gold Creek at Juneau for 1920.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
January	434	....	47.6	2,930	August	1,000	72	252	15,500
February	32	8.6	14.4	828	September	552	30	161	9,580
March	7	1.9	3.91	240	October	262	29	89.7	5,520
April	33	1.5	10.4	619	November	480	23	106	6,310
May	149	25	64.5	3,970	December	19	5.6	11.0	676
June	480	164	248.	14,800					
July	350	169	256.	15,700	The year	1,000	1.5	106	76,700

ORE DEPOSITS OF THE SALMON RIVER DISTRICT, PORTLAND CANAL REGION.

By Lewis G. Westgate.

INTRODUCTION.

Portland Canal, a steep-walled fiord, penetrates the Coast Range for some 90 miles from Dixon Entrance, at the southern boundary of Alaska, cutting obliquely across the trend of the mountains. This great trench through the mountains is extended northward by the alluvium-floored valley of Bear River, which reaches far back into the upland beyond the Coast Range (fig. 1). At 2 miles from its head Portland Canal is joined on the west by Salmon River, the mineral deposits of whose basin are here described. The valleys of Salmon and Bear rivers are separated by the Reverdy Mountains, a southward-trending spur of the main range. At the seaward end of this spur is the settlement of Hyder, which has a population of a few hundred people and is the ocean port, supply point, and post office of the Salmon River district. Its location is on the international boundary, and the steep slope immediately to the north has crowded the settlement onto the tidal flats, where it is in part built on piles. The newer part of the town, however, is in a better location to the northwest, on the gravel-floored Salmon River valley. Two miles to the northeast is the town of Stewart, on the British Columbia side of the boundary. Though older than Hyder, it has about the same population. The Salmon River region forms the southeastern part of the Ketchikan district.

Metal-bearing lodes, chiefly of gold and silver, were found in the Canadian portion of this region about 1898, and similar discoveries had been made on the Alaska side of the boundary by 1901. These deposits received relatively little attention until 1909, when a small boom was started in the Canadian district. This boom subsided in a few years, but meanwhile the town of Stewart and some 12 miles of railroad were built. Interest was revived in 1917 by the discovery of some rich silver ores on the Canadian side of the line, and in 1918 a commercial ore body was found at the Premier mine, which, though in the Salmon River basin, is also in Canada. As a result, many claims were staked on both sides of the boundary, and the town of Hyder sprang up. The upper part of the Salmon River basin lies in Canada, but its only practical mode of access is through

Alaska. (See fig. 1.) This lack of adjustment of the international boundary to the topography gives Hyder a much greater importance than it would have if it served only the Alaska portion of the district. Though no mines have been developed on the Alaska side, many claims have been staked, and on some of these, as will be shown, considerable work has been done during the last two years.

In view of the fact that the geologic features on the two sides of the boundary were known to be essentially the same, there appeared to be good hope that commercial ore bodies might be found in the Salmon River district. For this reason the writer undertook a geologic examination of the region, a task which occupied him from July 19 to August 17, 1920. Though the salient features of the geology are simple, the heavy vegetal cover below timber line greatly enhances the difficulties of field examination and increases the work of the prospector.

TOPOGRAPHY.

The region is one of mountainous topography and high relief. The floor of Salmon River and of its principal tributary, Texas Creek, rises from sea level to about 500 feet where they issue from their glacier sources. From these low valley altitudes the mountains rise steeply and in places by unscalable cliffs to heights between 5,000 and 6,000 feet. The highest points within the area examined are a little over 6,500 feet above the sea. The only level land in the district consists of the gravel-floored bottoms along Salmon River and Texas Creek The lower slopes, up to 3,000 feet or more, are covered with forest; at higher levels the mountains, where no covered by snow fields and glaciers, are largely bare rock. Even the narrower ridges along Portland Canal and the lower parts of Salmon River carry snow fields and small summit and cliff glaciers, and farther inland the larger valleys reach above snow line and serve as collecting basins for extensive ice fields, the sources of large valley glaciers. The snow line stands at about 4,500 feet, and the glaciers descend within 500 feet of sea level.

CLIMATE.

Portland Canal lies within the Pacific coast climatic province, an area of abundant rainfall and comparatively moderate temperature due to prevailing westerly winds from the Pacific Ocean. The annual precipitation at Fort Tongass,[1] near the entrance to Portland Canal, is about 130 inches; at the head of the canal it is less, possibly not far from 100 inches. The least rainfall occurs late in spring and early in summer, and abundant rains set in by September.

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 162-165, 1906.

From November to March the precipitation is in the form of snow. The summers are not hot, and the temperature seldom drops much below zero in winter.

COMMERCIAL CONDITIONS.

Hyder, being on tidewater, is readily accessible throughout the year to large ocean vessels, but in 1920 Hyder had no wharf, and all freight was landed by scows. Provisions can be purchased in both towns, and more elaborate equipment can be brought from Ketchikan, with which there is communication about twice a week by means of gasoline boat. The distance from Hyder to Ketchikan is 155 miles by the water route. Stewart has steamer communication with Prince Rupert, British Columbia, 135 miles distant.

Travel inland is difficult, except along the few established roads and trails. The best road in the region is the one connecting Hyder and Stewart (2 miles), which is suitable for automobiles.

Salmon River and Texas Creek are swift and practically impassable streams, which effectually divide the country through which they run. Texas Creek and Salmon River south of Ninemile flow in a network of channels through a broad valley bottom floored with coarse gravels. A road has been constructed up the east side of the Salmon to Elevenmile and thence to the Premier mine, in Canadian territory. Except at a few points where it is forced to the valley side by eastward swings of the river, the road follows the bottoms and is therefore subject to overflow and washout, as was well shown in the high-water stages of August, 1920. Above Elevenmile the road is on the valley slope. From the road three pack trails branch off, one in Canada to the Big Missouri and neighboring properties, one at Elevenmile to the New Alaska property, and one up Fish Creek to the Watkins and Tonkin properties.

The only crossing of Salmon River is a footbridge at Ninemile. From this point a foot trail leads to Texas Glacier and thence by a low saddle 3 miles above the mouth of the creek to Salmon Glacier. Most of the prospecting in the region is done by men who pack their outfits on their backs through country where there is not even a foot trail.

The valley bottoms and mountain slopes up to 3,500 feet are heavily forested, chiefly with hemlock and spruce. In the valley bottoms and on the lower slopes there is good timber in sufficient abundance for mining and other local needs.

As yet there has been no demand for water power, and the possibilities of developing it have not been closely scrutinized. Fish Creek and its tributary, Skookum Creek, the largest of the small streams, descend rapidly and are worth consideration as sources of power. There are no accurate records of their flow, which is greatly diminished in winter. The other streams in Alaska east of Salmon River are small and probably without value for power.

PUBLICATIONS.

The following references may prove useful to those wishing further information on the geologic features and ore deposits of the region.

Reports relating to Alaskan part of Portland Canal region.

Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred H. Brooks: U. S. Geol. Survey Prof. Paper 1, 1902.

The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright. U. S. Geol. Survey Bull. 347, pp. 1–210, 1908.

Notes on the Salmon-Unuk River region, by J. B. Mertie, jr.: U. S. Geol. Survey Bull. 714, pp. 129–142, 1921.

Mining developments in southeastern Alaska, by Theodore Chapin: U. S. Geol. Survey Bull. 642, pp. 94–98, 1916.

Reports relating to Canadian part of Portland Canal region.

Portions of Portland Canal and Skeena mining divisions, Skeena district, B. C., by R. G. McConnell: Canada Geol. Survey Mem. 32, 1913.

Northwestern district (No. 1), by Geo. A. Clothier: British Columbia Minister of Mines Ann. Rept. for 1917, pp. 68–73, 1918.

Northwestern district (No. 1), by Geo. A. Clothier: British Columbia Minister of Mines Ann. Rept. for 1918, pp. 76–83, 1919.

Northwestern district (No. 1), by Geo. A. Clothier: British Columbia Minister of Mines Ann. Rept. for 1919, pp. 61–80, 1920.

Salmon River district, Portland Canal mining division, B. C., by J. J. O'Neill: Canada Geol. Survey Summary Rept., 1919, pt. B, pp. 7b–12b, 1920.

The Premier gold mine, Portland Canal, B. C., by Charles Bunting: Min. and Sci. Press, vol. 119, pp. 670–672, 1919.

The geology of the Portland Canal district, by Victor H. Wilhelm: Min. and Sci. Press, vol. 122, pp. 95–96, 1921.

The Salmon River district, B. C., by S. J. Scofield and George Hanson: Canada Geol. Survey Summary Rept. for 1920, pt. A, pp. 6a–12a, 1921.

GEOLOGY.

GENERAL FEATURES.

The Salmon River district lies on the eastern margin of the great Coast Range batholith,[3] which parallels the shore line of British Columbia and southeastern Alaska from the United States and Canada boundary nearly to the meridian of Mount St. Elias, a distance of some 1,100 miles. It ranges in width from 20 to 110 miles and is the largest batholith on the American continent. It is generally believed that this great mass was intruded in Jurassic time and probably chiefly in Middle and Upper Jurassic time.[3a]

A reference to the map (fig. 1) will show that the inland margin of the batholith is irregular and invades the volcanic and sedimen-

[3] The term "batholith" is applied to bodies of igneous rock which occupy considerable areas and which widen downward. Unlike sheets and laccoliths, they are not known to be bottomed by other rocks. R. A. Daly (Igneous rocks and their origin, p. 90, New York, 1914) proposed that this term be used for large bodies, over 40 square miles in area, and that the term "stock" be reserved for the smaller bodies.

[3a] Since the above was written Scofield and Hanson have reported the occurrence of Mesozoic fossils, probably Jurassic, in the Nass formation: Canada Geol. Survey Summary Rept. for 1920, pt. A, p. 8a, 1921.

tary formations that lie to the east. On the Canadian side of the boundary, as shown by McConnell's map,[3] there are some outliers of

FIGURE 1.—Geologic sketch map of Salmon River district. Mines and prospects: 1, Stoner; 2, New Alaska, 3, Watson & Bain; 4, Fish Creek Mining Co.; 5, D. & A. Lindeborg; 6, Charles, Nelson & Pitcher.

granite within the area occupied chiefly by volcanic rocks and sediments.

[3] Canada Geol. Survey Mem. 32, 1913.

Only the following formations, in descending order, occur in the Salmon River district:

1. The gravel filling of the Salmon River valley.
2. Intrusive rocks of the batholith, chiefly of granitic type, with accompanying dikes.
3. A series of greenstones, which lie northeast of the batholith and, being cut by the granite rocks, are therefore older.

In the region east of the boundary McConnell has recognized three bedrock formations in addition to the intrusives. These are, in descending order:

1. Nass formation. Mostly argillites with some tuffaceous sandstones.
2. Bear River formation. Chiefly massive fragmental greenstone.
3. Bitter Creek formation. Argillites with some tuffs and limestones.

Certain greenstones on the Alaska side are regarded as the equivalent of McConnell's Bear River, with the reservation that some of the other formations may be included also.

GREENSTONES AND ASSOCIATED ROCKS.

Between the lower slopes of the Reverdy Mountains and the international boundary is a triangular area in which the bedrock is chiefly greenstone (fig. 1). The dominating rock within this area is a soft green and gray rock of indeterminate origin, but with it occur better-defined tuffs and breccias. These rocks are believed to be more or less altered volcanic rocks and from their prevailing color may be conveniently grouped together as "greenstones." On the Alaska side of the boundary the greenstones, owing to their proximity to the intrusives, are more highly altered than to the east, where their true character is more evident. It will be well, therefore, to quote McConnell,[4] who describes them as

> A series of massive and fragmental volcanics many thousands of feet in thickness, evidently representing the product of a long-continued period of volcanic activity. The rocks have a general greenish coloration, except in a few areas where they are reddened by the oxidation of their iron content.
>
> The rocks * * * have a wide range and include porphyrites of various kinds, mostly of hypabyssal origin, volcanic breccias and agglomerates, tuffs, and occasional argillaceous bands. Small areas in various parts of the district have been silicified and altered into a cherty condition.
>
> The fragmentals occur as tuffs and volcanic breccias and agglomerates. The tuffs are made up largely of feldspar crystals, often broken, quartz grains, and minute rock fragments lying in a dark fine-grained mat and are often difficult to distinguish in the field from the massive porphyrites. The breccias exhibit considerable diversity in character and probably originated in different ways. * * *
>
> Occasional dark argillaceous bands occur with both the massive and fragmental members of the Bear River volcanic group, apparently indicating that sedimentation occurred at intervals during the whole period of its accumulation.

[4] Op. cit., pp. 14-16.

The rocks of the Bear River formation usually occur in a massive condition but in places * * * have yielded to crushing, and a strong schistosity approximately paralleling the eastern edge of the Coast Range batholith and dipping towards it has developed.

The fragmental varieties * * * are seldom distinctly bedded or banded and are often remarkably uniform in composition through sections many hundreds of feet in thickness.

McConnell was able to make no close age determination of the Bear River formation other than that it was pre-Cretaceous, on the evidence that the granitic intrusives were later. In lithology the greenstones of the Salmon River district resemble certain Jurassic rocks of the islands to the west,[5] and this resemblance suggests that they are of early or middle Mesozoic age.

The different types noted by McConnell, with the exception of the porphyrites, were recognized on the Alaska side of the boundary, though with their original character more or less veiled toward the contact and obscured still more, by mineralization, at the mining prospects. Excellent tuffs and breccias, clearly recognizable as such both in hand specimens and under the microscope, are found along the international line between Elevenmile and the head of Fish Creek, and large boulders of the conspicuously marked breccia are abundant in the lower parts of the valleys heading against the divide. Throughout most of the area, however, the greenstone is a gray or green fine-grained soft calcareous rock, indistinctly banded and specked with minute grains of pyrite. Thin sections show aggregates of quartz, calcite, sericite, chlorite, and feldspar and usually pyrite and leucoxene or granular titanite. The micas are not abundant enough to give foliation.

The rock is rather uniform over considerable areas and ordinarily does not show any structure in the outcrop. Neither in the outcrop nor in the thin section is the original character of the rock to be seen. Areal variability in some thin sections suggests a tuff. There is nothing to suggest sedimentary origin. The uniformity of the rock and its mineral character indicate that it is probably either an altered tuff or a lava.

Near the mines and prospects the mineralization has been much more intense; indeed, the existence of the ores is a direct result of this mineralization. This is shown in the increase of silica to so great an extent that the rock is in places nearly a quartzite and in the abundance of pyrite, sphalerite, and galena and, in another type of occurrence, of pyrite, pyrrhotite, and chalcopyrite, the rock locally becoming an ore.

At a few points along the road above Texas Creek occur black argillites, which are clearly of sedimentary origin and which may be

[5] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo islands, Alaska: U. S. Geol. Survey Prof. Paper 120, p. 86, 1918.

interbedded in the tuffs. None of the conspicuously porphyritic porphyrites mentioned by McConnell were seen, though finely porphyritic varieties are probably represented by some of the greenstones. As it is difficult to destroy the structure of a porphyry completely, the general absence of any recognizable porphyritic structure in the greenstones is taken to mean that most of them are tuffs.

On Mount Dolly, at the south end of the greenstone area, the rocks are well bedded and are apparently sedimentary rocks, which strike between northwest and west and dip 70° N. They are in part dark-gray or green fine-grained rocks with abundant pyrite, which produces the conspicuous red color that the rocks show on weathering. Toward the top of Mount Dolly and nearer the granite contact the rocks become coarser-grained banded gneisses, characterized in the different layers by varying amounts of fine-grained hornblende, biotite, and epidote. The gneiss is cut both parallel with and across the bedding planes by narrow veinlike bands of quartz, with epidote and some garnet. The relation of these rocks to the tuffs farther north was not ascertained. If they are members of McConnell's Bear River formation, it here comprises many hundred feet of sedimentary rocks, now well metamorphosed.

GRANITE OF THE COAST RANGE.

Much the larger part of the Salmon River district is occupied by the intrusive rocks. These intrusives, here collectively termed granite, range in lithology from diorite and granodiorite to granite.[6] The contact between the granite and the greenstone to the northeast (fig. 1) crosses the Reverdy Mountains and the international boundary a little south of Mount Dolly, at an elevation of 4,500 feet. Thence it can be followed with ease to a point west of Mount Dolly, where it takes a course nearly due north. From this point to the place where it again crosses into Canadian territory the contact can not be located with accuracy, in part because of a heavy cover of forest vegetation and rock slides and in part because of the occurrence in the greenstones of numerous dikes of granite porphyry, many of them wide. Where vegetation covers the more easily weathered and hence lower greenstones, it is often difficult to determine whether the rock is a

[6] The term "granite," commonly applied to the rock of this batholith, is sufficiently accurate for ordinary usage, though in a strict petrographic sense the rock is usually not a granite. In this paper the term "granite" is used for a coarse-grained plutonic rock consisting of quartz and orthoclase feldspar; "diorite" for a rock of similar physical character which may or may not contain quartz but contains plagioclase feldspar; "granodiorite" for the intermediate type which contains orthoclase and plagioclase feldspar in approximately equal amounts. In each rock the additional biotite, hornblende, and common accessory minerals are assumed. Granodiorite is then, as the word itself at once suggests, intermediate between granite and diorite. "Monzonite" has been used for the intermediate type but is not so directly expressive. This usage does not conform to that proposed by Waldemar Lindgren (Granodiorite and other intermediate rocks: Am. Jour. Sci., 4th ser., vol. 9, pp. 269-282, 1900) and J. P. Iddings (Igneous rocks, vol. 2, pp. 43, 152, New York, 1913), but it is easier to apply and, for present purposes, less confusing. In the following pages "granite" is sometimes used in the general sense in referring to the rock of the batholith as a whole. It is clear from the context when the term is so used and when it is used in the narrower petrographic sense with reference to the particular composition of a part of the body.

dike or a part of the main granite mass. The difficulty is the greater because identical porphyritic intrusive rocks occur within the area of the granite itself. The whole situation is still further complicated by local shearing, which has changed both granite and dikes to gneissoid and even schistose facies. Even along Salmon River below Elevenmile, where numerous cuts have been made in road construction, it was impossible to locate the exact contact.

Although the rocks of the batholith have a broad conformity of composition and occurrence that justifies their being mapped and described as a unit, yet there are certain local variations that merit attention.

From Mount Dolly south to Hyder the intrusive is a uniform light-colored medium-grained massive rock, specked with small black grains of biotite and hornblende. The rock varies in composition; some of it is granite, but on the whole it is best described as granodiorite. Some darker streaks and patches (schlieren) occur, as well as dikes of white aplitic granite. The contact with the greenstone across Mount Dolly is perfectly sharp, and very few dikes from the granite cut into the earlier rocks. Pegmatite dikes are practically lacking; and in this respect the east margin of the batholith stands in marked contrast with the west margin.

The intrusive north of Fish Creek, especially toward the greenstone contact, is a much more varied rock than that about Hyder. The commonest type, itself rather variable structurally, is a greenish-gray medium-dark rock of medium to fine grain. It usually shows abundant black blades of altered hornblende as much as 1 centimeter in length, which in some places lie variously oriented in a common plane. It may be called a quartz-hornblende diorite.

There are some variations from this type. Locally orthoclase occurs in porphyritic crystals 1 or even 2 centimeters in length, and the rock becomes a granodiorite porphyry.

Farther north, in the valley of Texas Glacier and west of Salmon Glacier, a lighter rock prevails, resembling that about Hyder. Along the glacier tributary to Salmon Glacier south of station 6535 (fig. 1) it is a light medium-grained granodiorite. In the valley of Texas Glacier a similar rock is found, both in dikes cutting the darker granite and as abundant boulders brought down from the granite area farther west. This rock is normally porphyritic and is a granodiorite porphyry. These porphyritic varieties of the granite form a transition to the more distinct porphyries, which occur as dikes in the greenstone but which are found also within the granite area.

The west side of Salmon River south of Texas Creek was not visited on account of the practical impassability of the Salmon. From the east side of the river it appears to be an area of light granite quite like that about Hyder.

PORPHYRY DIKES.

Many porphyry dikes occur in the greenstone area, east of the granite contact to and beyond the international boundary. These rocks range in color from light to medium gray, and some are dark gray. They usually show small prisms of hornblende and flakes of biotite against a white ground of feldspar. Feldspar phenocrysts are hardly noticeable in the lighter varieties but become more conspicuous in the darker rocks.

These porphyritic dike rocks, genetically associated with the Coast Range batholith, are intermediate in structure between the deep-seated granitic intrusive rocks and extrusive lavas. For example, one having the mineral composition of a diorite or andesite might be equally well named an andesite porphyry or a diorite porphyry. As they occur in the field with dioritic and granitic rocks, the several varieties of rocks noted can properly be classed as granite porphyry, granodiorite porphyry, and diorite porphyry.

Over a dozen large dikes with a maximum width of 1,200 feet are exposed along the Salmon River road between Texas Creek and the boundary. To judge from their contacts with the greenstone, these dikes strike from 50° to 70° NW. and dip 50°–60° SW. They are more resistant to weathering than the greenstones, so that in the timber and even for some distance above timber line the softer greenstones are largely concealed and the porphyries seem more abundant than they really are. As they closely resemble the granites, it is impossible to draw the granite-greenstone boundary accurately.

Dikes of the same character as those found in greenstone also occur within the main granite area. Boulders from them are among the most abundant rocks brought down by the Texas Glacier, and they cut the less porphyritic granites along the lower 2 miles of its course. They were also found in the granite exposed along the road south of Ninemile, where the more basic varieties are diorite porphyries showing conspicuous but small plagioclase phenocrysts, in striking contrast to a gray-black ground.

The dike porphyries described above agree in character and in range of mineral composition with the nonporphyritic granitic intrusive rocks of the batholith, which themselves locally have porphyritic facies. In the greenstone area the borders of the dikes show but slight structural evidences of chilling. In many places where identical rocks occur within the main granite area they are in dike form, and it is sometimes possible to see a distinct contact between them and the adjacent granite. On the other hand, there are many places where the porphyries grade into the adjoining nonporphyritic rock and it is impossible to fix a definite contact. These relations may best be explained on the assumption that the porphyries are an essential part of the granite intrusion following closely

the formation of the main batholith. They represent slightly differentiated magmas intruded into both the greenstones and the earlier-formed granite. In the greenstones the invaded rocks were under considerable cover and perhaps were warmed by the adjoining granite, so that there was but little border chilling of the dikes. They came into the granite at a time when it was still hot, perhaps not completely solidified; hence the lack of sharp contacts in many places. The border granite is thus not simple but a rather complex intrusive body, ranging from a granodiorite or even from a rock closely approaching a granite to a diorite and structurally from a massive granitoid rock to a porphyry. The presence of these porphyries and the tendency of even the earlier massive granites to grade into porphyritic facies suggests that the cover was not very thick. This complexity is not, however, characteristic of the granite about Hyder.

ORE DEPOSITS.

CLASSIFICATION.

Both O'Neill [7] and Chapin [8] have classified the ore bodies of the Salmon River region as of two general types—disseminated deposits of low metallic content and quartz veins containing shoots of very high-grade ore.

The disseminated deposits lie in shear zones, in places without well-defined walls, and are described by O'Neill as "large deposits of ore which is a complex mixture of zinc blende, galena, chalcopyrite, and pyrite." He cites the Big Missouri property as containing examples of deposits of this type. Of the concentrated ore bodies occurring as fairly well defined fissures, that of the Premier mine, on the Canadian side of the boundary, is the best example. In view of the local interest in the Premier mine, it will be worth while to quote O'Neill's description of two specimens of ore from this property: [9]

> Pyrite, sphalerite, probably galena, and pyrargyrite are disseminated in a gangue of mixed quartz and calcite. The pyrargyrite is abundant.
>
> Pyrite, sphalerite, pyrargyrite, a little pyrargyrite with the pyrite, zinc blende, and probably galena in a gangue of quartz. I saw no calcite in this specimen.
>
> Qualitative tests on both samples showed the presence of lead, indicating galena. The soft black mineral gave much copper and antimony, with silver, indicating freibergite.

Of the occurrence of these deposits O'Neill says:

> The general regional shearing is not uniformly distributed but is concentrated in zones. Where the northwest or northeast ore-bearing veins cross such zones or where they cross one another there is an enrichment of the deposit in the form of native

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[7] O'Neill, J. J., Salmon River district, Portland Canal mining division, B. C.: Canada Geol. Survey Summary Rept. for 1919, pp. 10b–bb, 1920.

[8] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 480, p. 96, 1916.

[9] Op. cit., p. 10b.

silver. In some places a series of the later fissures cross a main zone at relatively close intervals, and the enrichment is spread along the zone between them. * * * Where the main zone of fissuring is wide, as on the Premier, and the cross fissures are strong, considerable amounts of very rich ore have been developed across most of the width of the main zone along the cross fissures and has spread along between the cross fissures.

Scofield and Hanson in their recent report[9a] have classified the ore bodies of the Canadian Salmon River district as follows:

1. Base-metal type: These are replacement and disseminated deposits in certain beds of tuffs and conglomerates, with some veins carrying base metals. "These deposits are roughly tabular, as they correspond in strike and dip with the beds with which they are associated." They carry pyrite, chalcopyrite, sphalerite, and galena, with a gangue of quartz.

2. Silver-gold type: "The ores of this type occur in veins and veinlike replacements in quartz porphyry and at the contact of the porphyry and tuffs. The large ore-chutes [shoots?] are lenticular in shape. The minerals present are pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, freibergite, pyrargyrite, and sulphantimonides and sulpharsenides, native silver, and gold. The gangue is rather abundant and is almost entirely quartz." The Premier ore body is cited as an example of this type.

3. Gold type: "A single ore body in No. 2 tunnel of the Premier mine is of this type. This is a siliceous heavy-sulphide deposit. Quartz and pyrite are the predominant minerals. Small quantities of chalcopyrite, sphalerite, and galena are present. Assays show high value in gold, but practically no silver."

The above descriptions refer to the ore deposits on the Canadian side of the boundary. The following types have been found on the Alaska side:

1. Disseminated replacement deposits of galena, sphalerite, and pyrite, mainly in the greenstones. Example, the deposits now being opened on the New Alaska property.

2. Disseminated and lenticular replacement deposits of pyrrhotite, with minor amounts of chalcopyrite and pyrite and a very little sphalerite, in the greenstone. Example, the pyrrhotite deposits on the New Alaska property just above Elevenmile and that on the east side of the Fish Creek Mining Co.'s property, on Fish Creek.

3. Quartz fissure veins carrying pyrite, galena, sphalerite, and locally tetrahedrite and a little chalcopyrite. In places barite is associated with quartz as a gangue mineral. Nearly all the quartz veins occur in the granitic rocks. Examples, the veins on Fish Creek and near Sevenmile on Salmon River.

[9a] Op. cit., pp. 9a–12a.

Up to the present time most of the underground work has been done on the quartz fissure veins, some of which include shoots carrying much gold and silver. These quartz veins strike N. 30°–60° W. Relatively few extensive openings have been made on the disseminated deposits, which appear to trend N. 70°–80° E.

RELATION OF ORE DEPOSITS TO THE GRANITE BATHOLITH.

The Salmon River ore deposits are close to the edge of the great area of granitic rock which follows the west coast, and this position they share with all the metalliferous lodes of southeastern Alaska. Such border deposits are not limited to either side of the batholith, nor are they of any one metal. The copper deposits in the Alexander Archipelago and the gold and sllver lodes from Ketchikan north are close to either the west side of the main body of granitic rock or to the smaller intrusions that lie outside that body and still farther west. The ore deposits of Salmon River are in a corresponding position near the east edge of the batholith. The contact farther north is in Canadian territory, but metal deposits of different kinds have been reported near it.

This relation is essential, not accidental. The deposits border the batholith because the metals which they carry were derived from the igneous rock while it was still hot.

DISTRIBUTION.

The disseminated deposits are practically limited to the greenstones. The only exception noted was the deposit of disseminated sulphides of the first type on the Charles claim, on the east side of Texas Creek, which are in sheared porphyry and granodiorite of the batholith. The quartz veins are practically confined to the granite area, though in one place (locality 8, fig. 3, Fish Creek Mining Co.) a quartz vein carrying sulphides occurs in the greenstone. The reason for this practical limitation of the quartz veins to the granite and of the disseminated deposits to the greenstones is believed to lie in the nature of the inclosing rock. The softer greenstones, at the prospects mainly altered tuffs, are thought incapable of retaining open fissures, so that in them the deposit was formed by replacement along shear zones. The granite seems to have been firmer and able to retain open fissures, hence it holds the typical veins. At the depth of the deposits at the time of their formation the granite was in the zone of fracture, and the greenstone in the zone of flowage.

ORIGIN.

These deposits occur in the greenstone near the granite batholith and even in the outer part of the batholith itself because they were formed by solutions escaping from the still hot granite magma

through the solidified border of the granite and into the surrounding greenstones. The common association of mineral deposits with the east edge of the batholith has long since been pointed out by Brooks.[10] McConnell,[11] without question, explains the Canadian occurrence just across the international boundary in the same way. If this is their origin, their time of formation is fixed as soon after the intrusion of the granite, probably in the Cretaceous period.

The deposits are believed to have been formed at considerable depths beneath the surface of that time and to be what Lindgren[12] has styled deposits formed at intermediate depths, by which he means at depths between 4,000 and 12,000 feet below the surface and at temperatures of 175° to 300° F. The present exposures are all less than 2,900 feet above sea level. The higher summits of the area rise to more than 6,000 feet. The Cascade peneplain has not been recognized in this district; if, however, as is likely, the rough accordance of summit levels is due to the former presence of a plain near that level, the highest of the present depo its would have been nearly half a mile below that surface. But these summits west of the Salmon are in granite, well beneath the top of the batholith; moreover, above the batholith there must have been a cover of the invaded rocks. The field relations suggest, though they do not demonstrate, that the deposits may well have been formed at a depth of more than a mile below the surface of that time. Further, the sulphides present (galena, chalcopyrite, sphalerite, and pyrrhotite) are those found in deposits formed at considerable depths. If these deposits were formed at the depth inferred it is easy to see why the softer greenstones should have been, as suggested above, below the zone of open fracture, even if the harder granites were not.

The deposits are primary sulphides laid down by solutions rising from a granitic magma. In the quartz veins and the disseminated deposits of the first type the sulphides are essentially contemporaneous. In the pyrrhotite deposits the pyrite and arsenopyrite are followed by the pyrrhotite, galena, and sphalerite, but even here the mineralization belongs to one general period. There is no evidence whatever of any enrichment by descending solutions, so that no marked change in depth is to be expected.[13] Further, there is almost no surface weathering. Here and there traces of malachite and limonite occur and the rock is slightly porous owing to the removal by solution of the more soluble constituents, but this is at the immediate surface.

[10] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, pp. 44-74, 1910.

[11] Op. cit., p. 24.

[12] Lindgren, Waldemar, Mineral deposits, 2d ed., p. 546, 1919.

[13] It should be noted, however, that Scofield and Hanson (op. cit., p. 11a) believe that the native silver found in some of the ores of the Premier mine is of secondary origin. No such occurrences have been found on the Alaska side of the boundary.

OUTLOOK FOR PRODUCTION.

No productive mine has yet been developed in the American part of the Salmon River basin, and only one (Premier) on high-grade silver ores in the Canadian part. The low-grade disseminated sulphide ores on the Canadian side have not yet been successfully worked. On the American side the only considerable underground workings are on Fish Creek. It is therefore impossible to make any predictions of the future of the district. The following considerations, however, will help to indicate where deposits are likely to be found and what changes in depth are likely to have taken place.

All the American prospects and properties lie east of Salmon River and Texas Creek, and the best are either in the greenstones or in the granite near its contact. The most promising of those opened up are the New Alaska disseminated deposits in the greenstones above Elevenmile and the quartz veins on Fish Creek. From the Fish Creek Mining Co.'s property small amounts of high-grade silver ore have already been shipped. Workable deposits may yet be found in the granite west of Salmon River and Texas Creek, but the evident igneous origin of the ores and the development of prospecting and mining in the region to date suggest that paying properties are most likely to be found in the greenstones or in the granite near its contact, and that they will become increasingly improbable toward the west, in the granite.

If, as has been pointed out, the deposits are primary sulphides and show no changes due to weathering or downward enrichment,[14] whatever change in depth they show must be the result of irregularities of original deposition. The deposits can be followed downward in the belief that they will average as well in depth as at the surface, at least for considerable distances.

MINING PROPERTIES.

STONER.

H. B. Stoner has twelve claims (see figs. 1 and 2), which lie three abreast adjacent to the international line on Boundary Creek and extend from the wagon road at Salmon River to timber line. Shallow cuts have been made at several places. The owner reports small returns from a silicified and pyrrhotized porphyry at the point marked "A" in figure 2. About 200 feet to the northeast there is an opening in slightly pyrrhotized greenstone. A second opening (B, fig. 2) has been made at an elevation of 960 feet, in fractured greenstone, a greenish-gray, very fine grained calcareous rock, without banding, carrying minute grains of pyrite. Sulphides occur in the greenstone in irregular streaks, some mainly sphalerite, others galena and pyrite. The former are reported to carry a little zinc

[14] See footnote 13, p. 130.

and silver and a trace of gold; the latter to assay a little gold, 20.5 ounces of silver to the ton, and 28 per cent of lead, the total value reaching $48.90 a ton.

NEW ALASKA MINING CO.

The New Alaska property (see figs. 1 and 2) includes a group of eight claims which lie west of the Stoner claims and extend from the flat of Salmon River at Elevenmile (elevation 350 feet) southeastward up the slope to an elevation of 1,800 feet. The first claims were located in 1912–13, and intensive work on the property began in 1919.

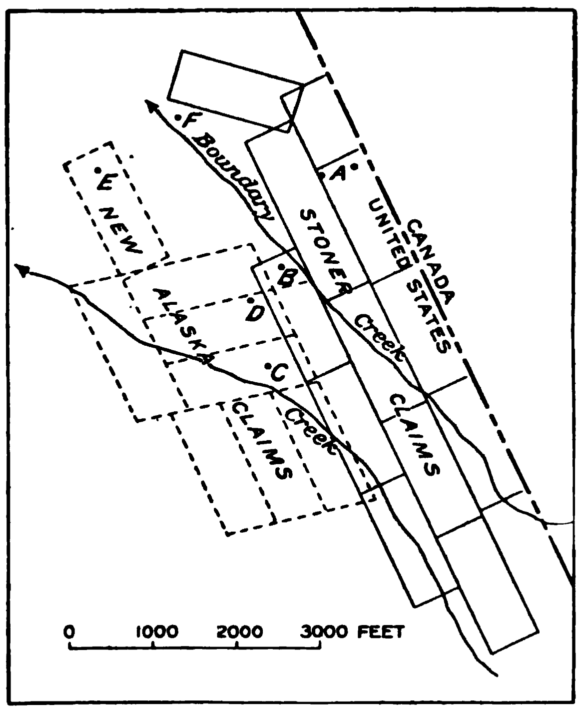

FIGURE 2.—Sketch map of Stoner and New Alaska properties, Salmon River district. See text for explanation of letters.

The main work has been done at an elevation of about 1,350 feet, on a ridge bearing N. 70° E. (fig. 2, C). A number of shallow cuts have been made, and a tunnel has been driven 114 feet across the strike of the rocks.

The country rock is a typical greenstone, probably an altered tuff or lava, and has much the same character at the different openings. It is a greenish-gray, rather soft, commonly calcareous, very fine grained rock, showing many small grains and crystals of pyrite. Hand specimens are cut by fine veins and patches of more coarsely crystalline calcite. An indistinct banded or bedded structure at some of the openings, which is perhaps a secondary structure, shows a strike between N. 45° E. and N. 80° E. and a steep dip to the northwest. The general trend of the mineralized belt is about N. 70° E., parallel to the course of the ridge. At many places the rock is shattered and broken.

Two kinds of mineral deposits occur on this property; one carries sphalerite, galena, and pyrite, and the other chiefly pyrrhotite. Only those of the first type are being developed. They lie in a system

of fracturing, in which certain zones are richer in sphalerite, galena, pyrite, with a very little chalcopyrite, than the others. These richer zones carry gold and silver. The greenstone lying within the zone of fracture is lighter colored than the normal country rock and carries a large amount of introduced silica and calcite. The difference between ore and country rock is a difference in the degree and kind of mineralization. There are no well-defined walls to the deposits, and the richer portions grade into the country rock. The introduction of the sulphides and silica seems to have been contemporaneous.

The best exposure is at the tunnel, which has been carried 114 feet in a direction N. 23° W., at right angles to the trend of the structure. For the first 50 feet from the portal the rock is a light greenish-gray fine-grained rock, here more siliceous, there more calcareous, and everywhere somewhat pyritized. Then follows 27 feet of a similar rock containing bands and patches of sulphides (sphalerite, galena, and pyrite). This is followed in turn by 15 feet of less mineralized rock and 10 feet of mineralized rock. The remainder of the tunnel is in barren rock, like that at the entrance. The rock structure at the entrance strikes N. 80° E. and has a nearly vertical dip, and the indistinct banding farther in agrees with this attitude.

The Hoosier prospect (D, fig. 2), north of the present workings and 350 feet lower, is on a different greenstone belt but repeats the conditions, both of country rock and ore, already described. A 10-foot opening has been made on a silicified greenstone. No well-defined structure was noted in the country rock, nor any distinction between vein and wall. Some of the silicified rock carries the usual sulphides.

The disseminated pyrrhotite ores of the second type are encountered in going north-northeastward from the present workings toward Elevenmile. In the upper part of this traverse there are several small exposures in which the greenstone carries a little pyrrhotite, pyrite, and galena, and at one of these exposures a 10-foot tunnel has been driven from which several hundred dollars' worth of ore is reported to have been mined. Near the bottom of the hill, not more than 200 feet above the river, two openings expose small bodies of pyrrhotite in the fine-grained greenstone. A thin section of the leaner ore shows irregular areas of pyrrhotite, a little sphalerite, and a very little chalcopyrite in a ground consisting mainly of quartz and sericite, with lesser amounts of chlorite and zoisite. A polished section of the massive pyrrhotite showed pyrrhotite and a very little chalcopyrite. The pyrrhotite is veined throughout by a fine network of later pyrite. Some pyrite occurs in the hand specimens. The pyrrhotite bodies have not been seriously worked. The indefinite banding of the country rock trends between northeast and east.

FISH CREEK MINING CO.

The Fish Creek Mining Co. controls 17 claims (see figs. 1 and 3), which lie mainly on the ridge between Fish Creek and Skookum Creek but extend to either side of these creeks, particularly west of Skookum Creek. Patents have been applied for on three of the claims—the Starboard, Olympia, and Nevada. The property was acquired by the present company in 1909, and more work has been done on it than on any other in the district. It is reported that 16 tons of high-grade ore was shipped in 1916–17.

The contact between granite and greenstone crosses the property in a direction a little west of north. Most of the openings are in rock that is more or less clearly recognized as belonging to the granite. One representative specimen obtained west of Skookum Creek is a granodiorite, showing quartz, plagioclase in excess of orthoclase, biotite much in excess of hornblende, though both had gone over completely to secondary minerals (chlorite, calcite, epidote, and quartz), and accessory apatite and magnetite. Nearer the veins the original character of the country rock is in many places masked by shearing and mineralizaton. The typical greenstone occurs on the east side of the property. All the quartz veins examined, except that at locality 8 (fig. 3), seem to be in granitic country rock. At locality 8 the rock is a slaty rock, which is more properly placed in the Bear River formation.

Ore bodies of two types occur in this group of claims—(1) quartz veins which carry galena, sphalerite, tetrahedrite, chalcopyrite, and pyrite, and (2) lenticular bodies of pyrrhotite, with small amounts of chalcopyrite and pyrite. So far as yet determined the quartz veins alone are of value.

Most of the underground work so far done on the property is on the Starboard and Olympia claims, where there are a series of quartz veins striking about N. 40° W. and dipping 45°–70° NE. Two tunnels have been driven on a well-defined vein on the Starboard claim. At the portal of the upper tunnel the vein measures 27 inches in width, strikes N. 40° W., and dips 70° NE. At an opening made on the hill slope a little above the tunnel the vein dips 80° SW., the only exception noted to the general northeasterly dip. The upper tunnel has been driven about 50 feet, but the vein has not been definitely recognized throughout this distance, and it is possible that the tunnel does not follow the vein throughout its length. The vein can be traced from the upper tunnel to Skookum Creek, a distance of about 400 feet. Near the creek it has been opened by a 40-foot tunnel, in which it strikes N. 35° W. and dips 65° NE.

The quartz vein contains galena, pyrite, and tetrahedrite, with some sphalerite and chalcopyrite, and shows a little copper stain (malachite). A polished section shows tetrahedrite, galena, and a

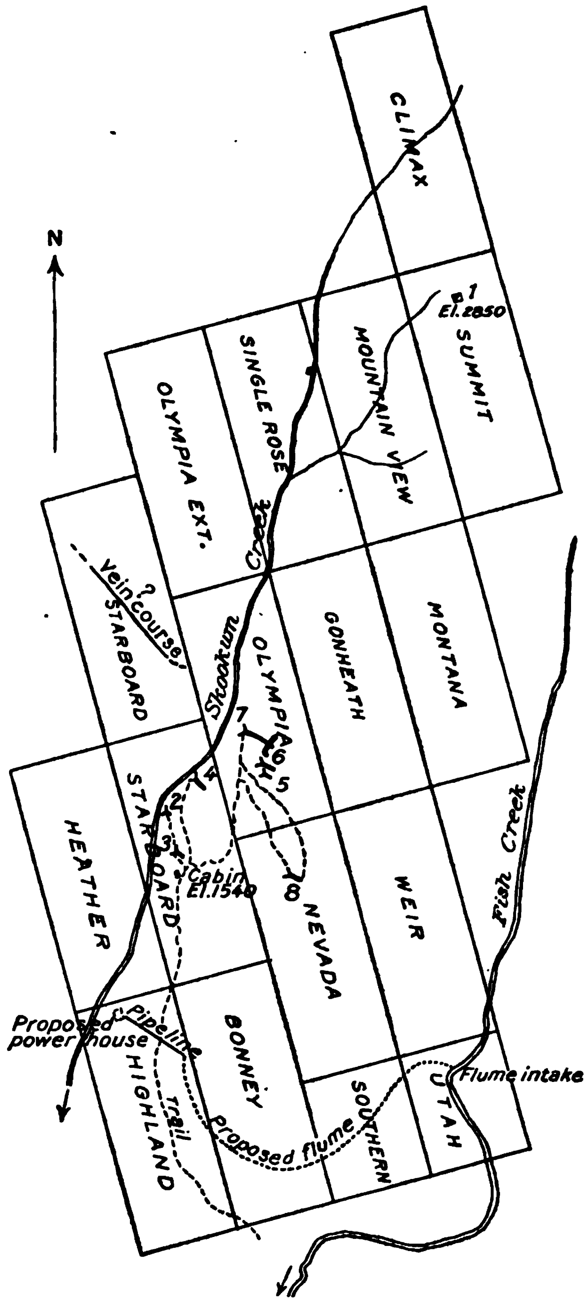

FIGURE 3.—Sketch map of Fish Creek Mining Co.'s properties, Salmon River district. See text for explanation of numbers.

little sphalerite and chalcopyrite, with no evidence of any notable difference in time of introduction of the minerals. The country rock is a sheeted porphyry with some slaty rock which bears N. 65° E. and dips 80° NW.

At locality 4, also on the Starboard claim, a 75-foot tunnel has been run in on a vein which at the entrance strikes N. 60° W., dips 65° E., and has a thickness of 3 feet 9 inches, with well-marked hanging and foot walls against broken granite. It can be followed, though not as a single vein, to the face of the tunnel and can be traced northwestward across Skookum Creek. The minerals it carries are galena, tetrahedrite, pyrite, and some chalcopyrite and sphalerite.

On the Olympia claim there are two tunnels on the same vein at localities 5 and 6. The upper one goes in 100 feet in a direction S. 55° E., to a point where the vein is lost by a fault. The strike of the fault is N. 30° E., and the dip about vertical. The lower tunnel does not go in far enough to reach the fault. The vein at the mouth of the upper tunnel is 19 inches wide, strikes N. 30° W., and dips 45° NE. The ore shows galena, tetrahedrite, sphalerite, a little chalcopyrite, pyrite, and some iron and copper (malachite) stain. Two polished specimens of the ore show tetrahedrite, with some sphalerite and pyrite and a very little chalcopyrite, in irregular areas cutting quartz. The sulphides are essentially contemporaneous.

At locality 7, on the Olympia claim, the longest tunnel on the property goes in on the vein 240 feet, to a point where the vein is cut off by a fault that strikes N. 30° E. and dips 60° NW. Drifts have been driven parallel to the fault in both directions, but the vein has not been recovered, unless a composite vein, offset about 50 feet to the southwest, is its continuation. The work had not been carried far enough to demonstrate this. From the mouth of the tunnel the vein can be followed on the surface northward perhaps 30 feet, to a point where it is cut out by a fault and broken zone that seems to have much the same direction as that at the face of the tunnel. The vein system in this part of the property is thus cut by a series of faults which run N. 30° E. and dip steeply northwest. As the rock is a massive granite or granite porphyry, it is very difficult to determine the direction and amount of displacement. This would be possible only if some of the veins could be identified on the opposite sides of the fault plane, and that has not yet been done.

The ore minerals of the vein are galena, tetrahedrite, and some pyrite. Rich specimens of the tetrahedrite ore have been found. A large specimen of high-grade ore is reported to have given 0.84 ounce of gold and 598 ounces of silver to the ton.

At locality 8 some tunnels, now caved, have been run on a quartz vein which strikes N. 70° W. and dips 55° NE. Pieces of good ore were found in the dump.

The following figures are taken from assay reports furnished by the company, representing lots of ore ranging from half a ton to 5 tons taken from tunnels on the Starboard and Olympia claims and shipped to the Tacoma Smelting Co. in 1916 and 1917.

Assays of ore from Starboard and Olympia claims.

	Gold (ounces to the ton).	Silver (ounces to the ton).	Lead (per cent).	Copper (per cent).
1	0.40	376	32.40	3.30
2	.21	161.14	18.30	1.96
3	.37	316.32	38.90	3.08
4	.15	110.36	32.50	Trace.
5	.18	103.36	[a] 1.51	[a] 21.4
6	.90	706.67	[a] 7.68	[a] 32.20
7	.30	205.40	[a] 13.9	[a] 17.40

[a] The copper and lead are apparently reversed in the smelter report of Nos. 5 and 6 and probably No. 7.

On the Olympia Extension a quartz vein bearing N. 50° W. has been opened by trenching for 600 feet. It shows an average width of 3 feet. The following assays were kindly furnished by the company:

Assays of ore from vein on Olympia Extension claim.

	Gold (ounces to the ton).	Silver (ounces to the ton).	Lead (per cent).	Copper (per cent).
1	Trace.	3	6.5	Trace.
2	0.36	12		
3	.46	118.5	13	2
4	1.42	94.8		
5	.92	72.5	14.5	2
6	1.60	23.6		
7	.32	4.4	2.5	Trace.

Four additional assays of samples from the same vein show gold, 0.52, 2.10, 1.20, and 0.42 ounces to the ton, and silver, 38.20, 177.90, 166.80, and 114.48 ounces to the ton.

The assays quoted above indicate the presence of high-grade silver ores, the value of which may be enhanced to some considerable extent by gold and copper.

A body of pyrrhotite occurs on the Summit claim (locality 1, fig. 3), on the east side of the property and near its north end. Here the country rock is a greenish-gray fine-grained greenstone marked by veins of calcite and abundant small crystals of pyrite. The microscope shows it to be composed almost wholly of secondary minerals, chiefly quartz and sericite. Abundant chlorite and calcite occur along seams, with leucoxene, pyrite crystals, and a little fine-grained orthoclase. A few large rounded quartz grains resemble the phenocrysts in rhyolite and suggest that the original rock may

have been a quartz porphyry. An indistinct bedding bears N. 70° E. and is nearly vertical. In this greenstone are masses of almost pure pyrrhotite. The largest measures about 5 by 12 feet at the surface and stands 6 feet above the water level in a shaft that was sunk in all 10 feet without reaching the bottom of the pyrrhotite. With the pyrrhotite there is a little chalcopyrite and quartz. A polished section of the ore shows mainly pyrrhotite, with small amounts of pyrite, arsenopyrite, chalcopyrite, and a little gangue, mainly quartz. The order of mineral formation seems to be pyrite, arsenopyrite, quartz, pyrrhotite, and chalcopyrite, the last two essentially contemporaneous. A polished section of the immediately adjoining country rock, which contains abundant sulphides, shows mainly quartz and some arsenopyrite, irregularly cut by pyrrhotite, finely veined by later pyrite, and chalcopyrite. The arsenopyrite appears to have been fractured before the introduction of the quartz and other sulphides. An assay of samples from this body was reported by the owner to give gold, 0.36 ounce to the ton; silver, 4 ounces to the ton; copper, 2 per cent.

WATSON & BAIN.

The Watson & Bain property includes five claims (No. 3, fig. 1) in lower Fish Creek valley, owned by John Hoveland and leased in July, 1920, by Hugh Watson and J. B. Bain. A sixth claim, owned by Pete Low, is included, and Mr. Low has an interest in the operation of the property. In August, 1920, work was on the point of being resumed by the lessees. The claims lie mainly between Fish and Skookum creeks, though they extend west of Skookum Creek and east of Fish Creek, as well as along Fish Creek below Skookum Creek. Three openings have been made.

On Fish Creek No. 1 claim two tunnels have been driven on a quartz vein that strikes N. 60° W. and dips 60°–70° NE. The country rock is a broken, sheared, and in places schistose rock of fine grain and undetermined origin. It may be either an inclusion of the greenstone in the granite or a zone of shearing in the granite or granite porphyry itself. The two tunnels are about 75 feet apart vertically; the upper one is 50 feet in length, and the lower one 90 feet. The vein is irregular and of variable width; at the face of the upper tunnel it is 3 feet wide. It carries galena and some pyrite in a gangue of quartz, and some specimens show free gold. Selected samples have shown a high content of gold and silver.

On Fish Creek No. 2 claim a vein bearing N. 50° W. and leading down to Skookum Creek has been opened at intervals for 500 feet. The country rock is a greenish granodiorite. It is massive at a distance from the vein, but near the vein it is broken and mashed and shows small grains of introduced pyrite. A thin section of the less-altered rock shows plagioclase, quartz, and accessory titanite,

apatite, and magnetite, with secondary biotite, epidote, sericite, calcite, and chlorite. Fracturing of the rock and granulation of the mineral grains are conspicuous. At the upper opening there is one 1-foot quartz vein and several parallel veins 3 inches or less in width. Locally barite is an abundant vein mineral. The vein strikes N. 30° W. and dips 35° NE. The quartz holds scattered grains and stringers of pyrite. At 150 feet to the northwest the vein is 4 feet thick and contains pyrite, tetrahedrite, and a little copper stain (malachite). A polished section of the ore shows a gangue of quartz and barite cut irregularly by sulphides (tetrahedrite, with less amounts of pyrite, chalcopyrite, and a little sphalerite), which are essentially contemporaneous. Other openings trace the vein to Skookum Creek.

On the east side of Skookum Creek, just at its mouth, a quartz vein bears up the hill in a direction N. 23° E. and cuts an altered and somewhat pyritized greenish granitic rock. Just at the creek the vein is over 3 feet thick, strikes N. 30° E., and dips 45° SE. Farther northeast the dip is steeper; at the last point where it is opened by a shaft the strike is N. 45° E. and the dip 50° SE. The vein is here cut off by a fault, which strikes N. 15° E. and dips 85° NW. The vein at this point is 3 feet thick but splits below into two separated by a horse of country rock 1 foot wide. The ore is mainly on the footwall side. The vein carries galena. Assays of the lodes of this property are not available.

LINDEBORG.

D. & A. Lindeborg have claims east of the Salmon River road a little above Sevenmile (No. 5, fig. 1). These claims lie within the granite area, in a sheared granite porphyry. Two tunnels have been driven at different levels on a quartz vein that strikes N. 60° W. and dips 60° NE. The lower tunnel, 75 feet long, discloses a main quartz vein and some small parallel stringers of quartz in the adjacent country rock, particularly on the footwall side. The quartz carries pyrite and some galena and chalcopyrite; a little copper stain shows. A good deal of galena with some pyrite and a little chalcopyrite is found in the adjacent rock, especially on the hanging-wall side.

At the mouth of the upper tunnel a 3-foot vein of quartz is exposed. The hanging-wall half of the vein carries pyrite in fairly regular bands, some of them 3 to 4 inches thick. These general relations repeat those at the lower tunnel.

CHARLES, NELSON & PITCHER.

John Charles, Max Nelson, and Jim Pitcher hold claims on the east side of Texas Creek 2 miles above Salmon River (No. 6, fig. 1). The country rock is a greenish sheared facies of the granite porphyry

of the granite area. It is cut by small quartz veins, but the sulphides (sphalerite, galena, pyrite, and chalcopyrite) do not occur in the veins but are disseminated in the silicified porphyry. Assays from an opening to the north and a little up the hill are reported to show small quantities of gold, silver, and copper. The country rock here is a granodiorite. The thin section shows plagioclase (oligoclase) in distinct crystals, quartz, orthoclase graphically intergrown with quartz, and biotite, wholly altered to secondary products, with secondary calcite, sericite, leucoxene, and quartz. Much calcite and some pyrite have been introduced.

MISCELLANEOUS PROSPECTS.

About a quarter of a mile south of the Ninemile roadhouse a 40-foot opening has been made along a broken zone in the granite. This opening exposes a quartz vein 6 to 8 inches thick, accompanied by small quartz veins in the crushed country rock. The lead bears N. 25° W. and dips 55° NE. Several prospectors were in the field in August, 1920, but no discoveries except those noted above are known to have been made.

GEOLOGY OF THE VICINITY OF TUXEDNI BAY, COOK INLET.

By Fred H. Moffit.

INTRODUCTION.

Location and area.—The district considered in these notes includes Chisik Island and an area of about 225 square miles of mainland, approximately square in outline, extending from the south shore of Tuxedni Harbor[1] and Tuxedni Bay southward toward Chinitna Bay, as far as Red Glacier, but it does not include the head of Tuxedni Bay, which was not visited by the field party in 1920. Interest in this area lies chiefly in the relation of its rocks to the oil-bearing sediments of Oil and Iniskin bays, to the south, and the possibility of oil production within it.

Tuxedni Bay was visited by Martin and Stanton in 1904, and a detailed description of the rocks is contained in the account of the Iliamna region[2] published in 1912. A further report dealing especially with the oil possibilities of the district has recently been prepared by Martin.[3] The work of 1920 had as its objects the making of a topographic map of the coast of Cook Inlet from Tuxedni Bay to Iliamna Bay and a study of the geology with reference to the possibilities of producing oil. These objects, however, owing to various difficulties, were accomplished only in part.

Outline of geography.—The area outlined above extends from the shore of Cook Inlet westward to Mount Iliamna and the high mountains on the north-northeast. It is a rugged country that consists principally of the flanking mountains of the main range and includes little flat land except the valley of Johnson River. The maximum relief is 10,017 feet (Iliamna Peak), but the average elevation, exclusive of Mount Iliamna and the ridge north of it, is under 4,000 feet. The flanking mountains trend parallel to the west shore of Cook Inlet and conform with the trend of the major geologic structure. These mountains consist chiefly of sandstones and soft shales dipping from 10° to 25° or possibly 30° ESE. Their gentle eastern slopes are dip slopes, and their abrupt western slopes are scarp faces. Erosion has dissected them deeply, and they are profoundly glaciated.

[1] Commonly known as Snug Harbor, but called Tuxedni Harbor by decision of United States Geographic Board.

[2] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59-64, 1912.

[3] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 42-55, 1921.

The chief stream within the area is Johnson River, which heads in a large glacier on the side of Mount Iliamna and flows eastward into Cook Inlet. The level valley bottom on each side of the river is crossed by small sluggish streams and dotted with numerous beaver ponds. Most of the valley bottom is impassable for pack horses because of marshy ground, so that considerable time and labor may be required in crossing the valley. In times of high water during the warm summer days Johnson River is difficult to ford with horses because of swift water and quicksands.

Up to an elevation of about 2,000 feet the area is covered by a dense growth of alders, which make travel with horses absolutely impossible until a trail has been cut. Through the alders, both on the hill slopes and in the valley bottoms, are scattered cottonwoods in groves and as individual trees. Spruce, except a few scattered trees on Chisik Island and at Fossil Point, does not grow on the shores of Tuxedni Harbor, but it occupies much of the narrow coastal plain extending southward from the mouth of Johnson River to Chinitna Bay, and in the vicinity of Chinitna Bay it furnishes pilings for fish traps and for the wharf at the cannery in Tuxedni Harbor.

DESCRIPTIVE GEOLOGY.

GENERAL SECTION.

The distribution of the geologic formations in the vicinity of Tuxedni Harbor and Tuxedni Bay is represented on the map (Pl. II) and in the following table, which is based largely on the work of Martin:

	Feet.
Quaternary: Sands, gravel, morainal, and other unconsolidated deposits.	
Upper Jurassic:	
Naknek formation; shale, sandstone, arkose, andesitic tuff, and conglomerate	5,000
Chisik conglomerate; coarse conglomerate, of variable thickness, consisting predominantly of well-rounded granite pebbles in an andesitic tuffaceous matrix	290
Chinitna shale; fairly homogeneous marine sedimentary formation consisting of soft shale with subordinate amounts of sandstone and limestone	1,300–2,400
Middle Jurassic: Tuxedni sandstone; marine sedimentary formation consisting predominantly of sandstone but including a large proportion of shale with subordinate conglomerate and limestone	1,100
Middle or Lower Jurassic: Granite, granodiorite, and quartz diorite.	
Lower Jurassic (?): Lava flows cut by later intrusives.	

The thicknesses shown are those given by Martin, but it is probable, as he points out, that the Tuxedni sandstone is much thicker than is indicated in the table.

The excellent exposures of geologic formations on the coast of Chisik Island and Tuxedni Bay were studied in detail by Martin and Stanton, and the carefully measured sections made by them are given

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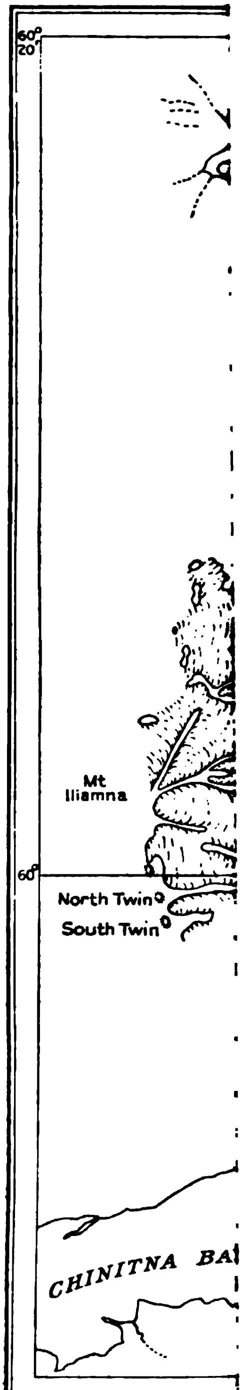


Topography by C.P. McKinley
Surveyed in 1920

in the account by Martin.[4] Additional collections of fossils were obtained from these formations in 1920, yet little can be added to the descriptions of the rocks themselves, although they were carefully studied in order that the geologists might familiarize themselves with the sections.

The axis of the main range of mountains, which extends north and south from Mount Iliamna, is made up of granite or of granitic rocks. This granite in the vicinity of Tuxedni Bay is bordered on the east by a belt of volcanic rocks averaging about 5 miles in width and making up many of the high mountains of the district. The volcanic rocks and the granite which intrudes them are not oil bearing and will not here be described in greater detail, although they may contain deposits of metallic minerals. The volcanic rocks in turn are succeeded on the east by a great thickness, approximately 9,000 feet, of sedimentary beds, which form the principal subject of this report. They are the rocks assigned to the Middle and Upper Jurassic epochs in the table and consist chiefly of shales and sandstones but include many beds of conglomerate. It is believed that the contact of these sedimentary beds with the volcanic rocks on the west is a fault contact. The beds have a fairly uniform easterly dip averaging about 20° but diminishing from the west toward the east. They are described briefly below.

MIDDLE JURASSIC ROCKS.

TUXEDNI SANDSTONE.

The type locality of the Tuxedni sandstone is on the south shore of Tuxedni Bay, where it is exposed in practically continuous outcrops for about 2½ miles. This section, however, does not include an unknown thickness of beds overlying the beds exposed on the shore of the bay. The rocks of this formation extend southwestward from Tuxedni Bay in a narrow belt that reaches into the Alaska Peninsula, but they are not known to be present on the north side of the bay, although they probably continue in that direction and may sometime be found there.

The formation is made up of marine sediments comprising alternating beds of sandstone and sandy shale which range in thickness from 1 foot to 100 feet. Although the top of the formation was not determined in 1920 it is known that more than 1,000 feet of sediments, chiefly shale, lie above the beds exposed on the shore of the bay, as is shown in the ridge between Tuxedni Harbor and Johnson River. It appears, therefore, that the minimum thickness of 1,128 feet given by Martin must be increased, possibly to 3,000 feet. A notable feature of the sandstone members that crop out on the shore of Tuxedni Bay is that in considerable part they were formed of material result-

[4] Martin, G. C., op. cit.

ing from the rapid weathering of igneous rocks, which were probably granite or related granitic rocks, for the sandstones contain an abundance of angular feldspar and ferromagnesian minerals.

The Tuxedni sandstone is the lowest known formation of the Middle Jurassic series in southwestern Alaska. It contains an abundant invertebrate fauna and has yielded good collections of plants.

The Tuxedni sandstone, like the beds overlying it, dips away from the high mountain axis toward Cook Inlet. The strike is about N. 30° E., parallel to the coast line of the inlet. The dip is slightly undulating and ranges from 15° to 25° E. The sedimentary beds of the Tuxedni Bay district flatten out toward the inlet. In a few places small open folds were seen, but otherwise the nearly uniform easterly slope of the beds appears to be uninterrupted.

UPPER JURASSIC ROCKS.

CHINITNA SHALE.

The Chinitna shale is a marine sedimentary formation occupying the base of the Upper Jurassic section on Cook Inlet. Its type locality is Chinitna Bay, where it is well exposed on both the north and south shores, but it extends in a narrow belt a mile or more wide along the east side of the Tuxedni sandstone, appearing on the south shore of Tuxedni Harbor and on the west side of Chisik Island. It consists chiefly of dark argillaceous shale but contains subordinate beds of sandstone and limestone. Its thickness, as measured by Martin, is nearly 2,400 feet. So far as is now known the Chinitna shale rests conformably on the underlying Tuxedni sandstone and differs from it, as pointed out by Martin, in that its shales are argillaceous rather than arenaceous. In general it has the same strike as the Tuxedni sandstone, about N. 30° E., but it has a lower average dip and in the vicinity of Tuxedni Harbor was not found to be folded except for the eastward tilting of the beds.

CHISIK CONGLOMERATE.

The Chisik conglomerate forms a conspicuous cliff on the north and west side of Chisik Island and is well developed also on the south side of Tuxedni Harbor. It includes several hundred feet of coarse conglomerate in which are included beds of finer conglomerate and of sandstone. Boulders and cobbles of granite and other granitic rocks are abundant in the conglomerate outcrops of Chisik Island. The matrix containing the pebbles and cobbles, according to Martin, is an andesitic tuff. The Chisik conglomerate is variable in composition and in thickness. Seemingly it is much less well developed south [illegible]dni Harbor, although it appears in the mountain south of J[illegible].

Fossils have not been found in the conglomerate, but it lies between formations of Upper Jurassic age, and it is therefore assigned to the Upper Jurassic.

NAKNEK FORMATION.

The Naknek formation is of heterogeneous composition and includes more than 5,000 feet of interbedded shale, sandstone, arkose, andesitic tuff, and conglomerate. It forms a belt averaging 4 or 5 miles in width along the coast of Cook Inlet from Chisik Island to Iniskin Bay and continues beyond that into the Alaska Peninsula. The shale, tuff, and arkose are best developed in the lower part of the formation. The upper part consists largely of massive light-colored sandstones which form the mountain slopes toward the coast but are more conspicuous because of the prominent westward-facing cliffs made by their scarps. These cliffs, owing to their light color and steep faces, are very noticeable topographic features when seen from the landward side but are less prominent when seen from the inlet.

The most complete section of the Naknek formation that has yet been measured is exposed on the north shore of Chinitna Bay, where it was studied by Martin and Stanton in 1904.

Fossils are not numerous throughout the Naknek formation but are locally abundant and fill thick beds. From their evidence the Upper Jurassic age of the formation is determined.

The strike of the Naknek formation is parallel to the shore of the inlet in the vicinity of Tuxedni Harbor and in the small area under consideration shows little deviation. The dip ranges from 10° to possibly 20° E. and in general is lower than that of the underlying sedimentary beds. No reversed dips or minor folds were observed in this formation.

QUATERNARY DEPOSITS.

The Quaternary deposits of Tuxedni Bay and the area adjacent on the south include glaciofluvial and beach deposits made up of re-sorted glacial débris, stream gravels, and the gravels and sand deposited by the sea.

Typical glacial deposits are not well developed except in the vicinity of the existing glaciers. The stream and beach gravels, however, contain an abundance of foreign material which was undoubtedly brought in by the ice and was contributed directly to them or was derived from the destruction of previous glacial deposits. The area is profoundly glaciated and must have supplied an immense quantity of débris to the moving ice. Part of this débris was carried to the sea, but another part was left on the land and was thus subjected to re-sorting and redistribution by streams.

The valleys of Bear Creek and Johnson River furnish the best examples of these re-sorted deposits, but the gravels of glacial origin

are so thoroughly intermingled with gravels of stream origin that no distinction between them is possible.

Johnson River in part of its course has cut through the surface deposits and reveals a bed of fairly coarse gravel tightly cemented with iron oxide, forming a hard conglomerate. This bed is conspicuous because of its bright color and contains a large proportion of fragments of vesicular lava, from which the cementing material and consequently the color was derived. The source of the lava was not visited, but it is believed to have come either from some comparatively recent flow from Mount Iliamna or else from the volcanic rocks underlying the Tuxedni sandstone. So far as is known the stream gravels are not gold bearing, but they are difficult to prospect and little attention has been given to them.

The beach deposits form a narrow border along the shore for the most part, but on the north side of Tuxedni Bay and north of Chinitna Bay they widen to a narrow coastal plain which in one place has a breadth of over 2 miles.

STRUCTURE.

The structure of the sedimentary beds in the vicinity of Tuxedni Bay has been indicated in the descriptions already given and is shown on the section on the map (Pl. II). These beds from the Tuxedni sandstone to the Naknek formation have a moderate easterly dip toward the shore of Cook Inlet and strike parallel to the shore, or about N. 30° E. A slight flattening of beds near the coast line is noticed, for the average dip there is between 10° and 15°, as compared with 20° or more at the upper end of Tuxedni Bay. The rarity of local variations in dip is notable. Folds and even short undulations in the beds are uncommon, although it should be said that the dense covering of alders on all the lower hill slopes obscures the structure in many places and possibly conceals folds that are present.

Faults of small displacement were observed at different places, but no great faults were seen within the area of the sediments. It is probable, however, that the contact of the Tuxedni sandstone with the underlying volcanic rocks is a fault contact. Martin,[5] from his study of the relations between the volcanic rocks, the Tuxedni sandstone, and the Chinitna shale in Chinitna Bay, reached the conclusion that the sedimentary beds are most probably separated from the volcanic rocks by a fault of considerable vertical and longitudinal extent, although he suggests other possible explanations of the relations existing there.

Although the Jurassic beds in the vicinity of Iniskin Bay and Oil Bay are known to carry a certain quantity of petroleum, as is shown

[5] Martin, G. C., op. cit. p. 97.

by oil seeps and drilling, the structure of these beds in the vicinity of Tuxedni Bay is not considered to be especially favorable for the accumulation of oil, for, so far as observation has shown, the structural features commonly considered as favorable or necessary for the retention of oil within an oil reservoir are not well developed here. On the other hand, the sedimentary beds themselves are seemingly as favorable for the development of the oil as the corresponding beds farther south. The petroleum of Iniskin and Oil bays is believed to be derived from the lower part of the Tuxedni sandstone and is stored in the porous beds of that formation. If the lower beds of the Tuxedni sandstone in the vicinity of upper Tuxedni Bay have ever been oil bearing, it seems likely that much of the oil has escaped to the surface and been lost during the long time that these upturned beds have been exposed to erosion, yet they may possibly still contain oil stored either in lenticular sand beds surrounded by impervious shale or in sand beds sealed by being faulted against impervious shale.

If the deeply buried part of the formation in the area nearer the inlet is oil bearing, it is unfavorable from the standpoint of the driller because of the great thickness of overlying beds that must be penetrated in order to reach the oil. The depth of the drill hole would be not only the thickness of the beds but an added depth due to the tilt of the beds, which, however, in beds of low dip is not great. The maximum depth to the top of the Tuxedni sandstone near the entrance to Tuxedni Harbor is at least 5,000 feet. Drilling in this vicinity would therefore seem unadvisable unless much more favorable structural conditions should be discovered than are now known.

GOLD LODES IN THE UPPER KUSKOKWIM REGION.

By George C. Martin.

DISCOVERY AND DEVELOPMENT.

The recent discovery of deposits of high-grade gold ores in the upper Kuskokwim region has attracted attention to a part of Alaska that is comparatively little known either to the general public or to mining men or geologists.

For several years a few small placer mines have been worked on Ruby and Hidden creeks, which are tributary to Nixon Fork from the south. In the course of this placer mining it was found that the gold became more abundant as it was followed up the creeks, but that above certain points it was no longer found. Shafts sunk into the bedrock at the limits of the placer gold revealed rich gold-bearing lodes lying on or near a monzonite-limestone contact. Further prospecting at this contact revealed the presence of other gold lodes. Shafts were sunk early in 1919 on two of the more promising of these lodes, and from one of them several hundred tons of high-grade ore was mined in the winter of 1919–20. This ore was sledded to Kuskokwim River and in the summer of 1920 it was shipped to the Tacoma smelter. In the meantime prospectors had traced the contact of the monzonite boss near the margin of which the known lodes lie, had staked claims along probably the entire contact, over much if not all of the monzonite area, and over part of the surrounding limestone, and had dug many trenches and pits along the contact and at other places, revealing the presence of many ore bodies of different sizes and richness. Many of the more promising claims, including the one from which ore had been shipped, passed into the control of the Alaska Treadwell Gold Mining Co. and associated interests early in 1920. During the summer of 1920 the Alaska Treadwell Co. was actively engaged in prospecting its holdings, and prospecting was being continued on a smaller scale on some of the other claims.

SOURCES OF INFORMATION.

Although the lower part of Kuskokwim River was explored in 1832, information concerning the upper part is still scanty. Several prospectors visited the upper part of the river between 1889 and 1898.

The earliest precise information concerning the country through which the upper river flows was gained by J. E. Spurr [1] and W. S. Post, who, in the summer of 1898, crossed the Alaska Range at the headwaters of Skwentna River and of the South Fork of the Kuskokwim and descended the Kuskokwim to its mouth (Pl. III). The resulting geologic information and maps of the area adjacent to the river from the forks to McGrath have been used in this report. In 1899 Lieut. Joseph S. Herron [2] crossed the Alaska Range at the head of Kichatna River and explored areas on various tributaries of the Kuskokwim above the forks. In 1901 a steamer was taken up the Kuskokwim to the forks. In 1902 an expedition under the leadership of Alfred H. Brooks [3] crossed the Alaska Range through Rainy Pass, near the headwaters of the South Fork of the Kuskokwim, and traveled northward along the western base of the Alaska Range. In 1907 G. B. Gordon [4] reached the headwaters of the North Fork of the Kuskokwim by way of Kantishna River and Minchumina Lake and descended the Kuskokwim to its mouth. Gordon's account of his explorations contains some general information on the region and much information concerning the natives but very few accurate cartographic or geologic data. A preliminary railroad survey from the Susitna Valley to Iditarod by way of the South Fork of Kuskokwim River was made in 1914 by J. L. McPherson for the Alaskan Engineering Commission.

Information bearing upon this district is to be found in descriptions of neighboring districts, notably in accounts by Smith [5] of an area on the south, by Eakin [6] of an area on the northeast, and by Mertie and Harrington [7] of an area on the west.

The prospects in the district have been described by J. S. Rivers [8] and by an anonymous writer [9] and have been briefly mentioned by Brooks and Martin.[10]

The statements herein presented are based primarily on observations made by the writer in a brief visit in the summer of 1920, but they include also such other information as could be gathered from various sources. Acknowledgment should be made for aid

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31-264, pls. 7-13, maps 4-14, 1900.

[2] Herron, J. S., Explorations in Alaska, 1899, for an all-American route from Cook Inlet, Pacific Ocean, to the Yukon: War Department, Adjt. General's Office, No. 31, 1901, pp. 1-77, with maps.

[3] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 234 pp., 18 pls., 1911.

[4] Gordon, G. B., In the Alaskan wilderness, 247 pp., 1917.

[5] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, 162 pp., 12 pls., 1917.

[6] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 54 pp., 8 pls., 1917.

[7] Mertie, J. B., jr., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 642, pp. 223-266, pl. 11, 1916.

[8] Rivers, J. S., Eng. and Min. Jour., Aug. 21, 1920.

[9] Min. and Sci. Press, vol. 121, pp. 475-476, 1920.

[10] Brooks, A. H., and Martin, G. C., The Alaskan mining industry in 1919: U. S. Geol. Survey Bull. 714, p. 93, 1921.

rendered to the writer in the field and for information furnished by all the local claim owners, miners, and prospectors and especially by Mr. Livingston Wernecke, who was in charge of the local operations of the Alaska Treadwell Mining Co. Much of the information here presented would not have been available without Mr. Wernecke's cordial and generous cooperation.

GEOGRAPHIC ENVIRONMENT.

POSITION.

The lode prospects to be described are about 12 miles north of the forks of the Kuskokwim. (See fig. 4.) The forks are in west-

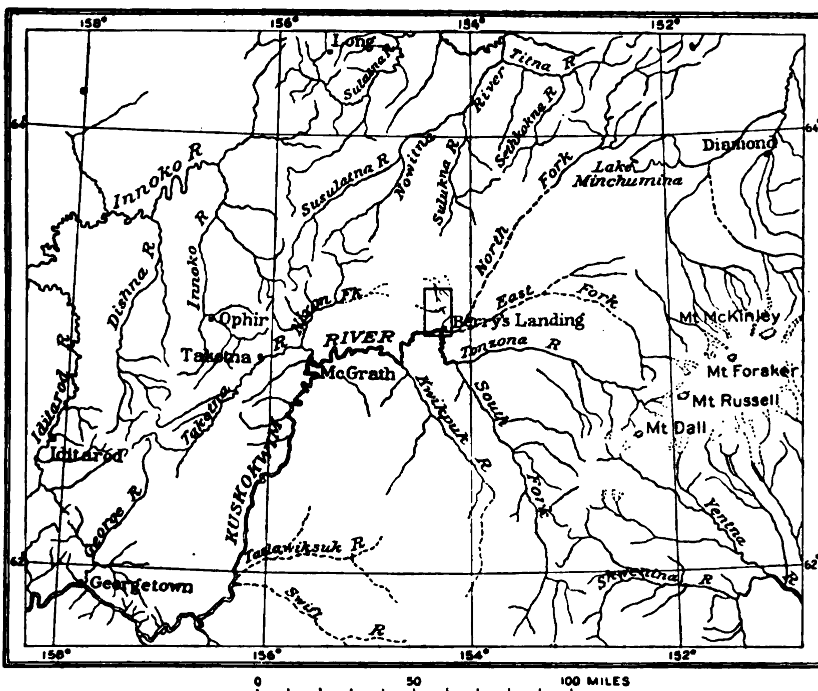


FIGURE 4.—Index map of upper Kuskokwim basin. The rectangle indicates the area shown in figure 5.

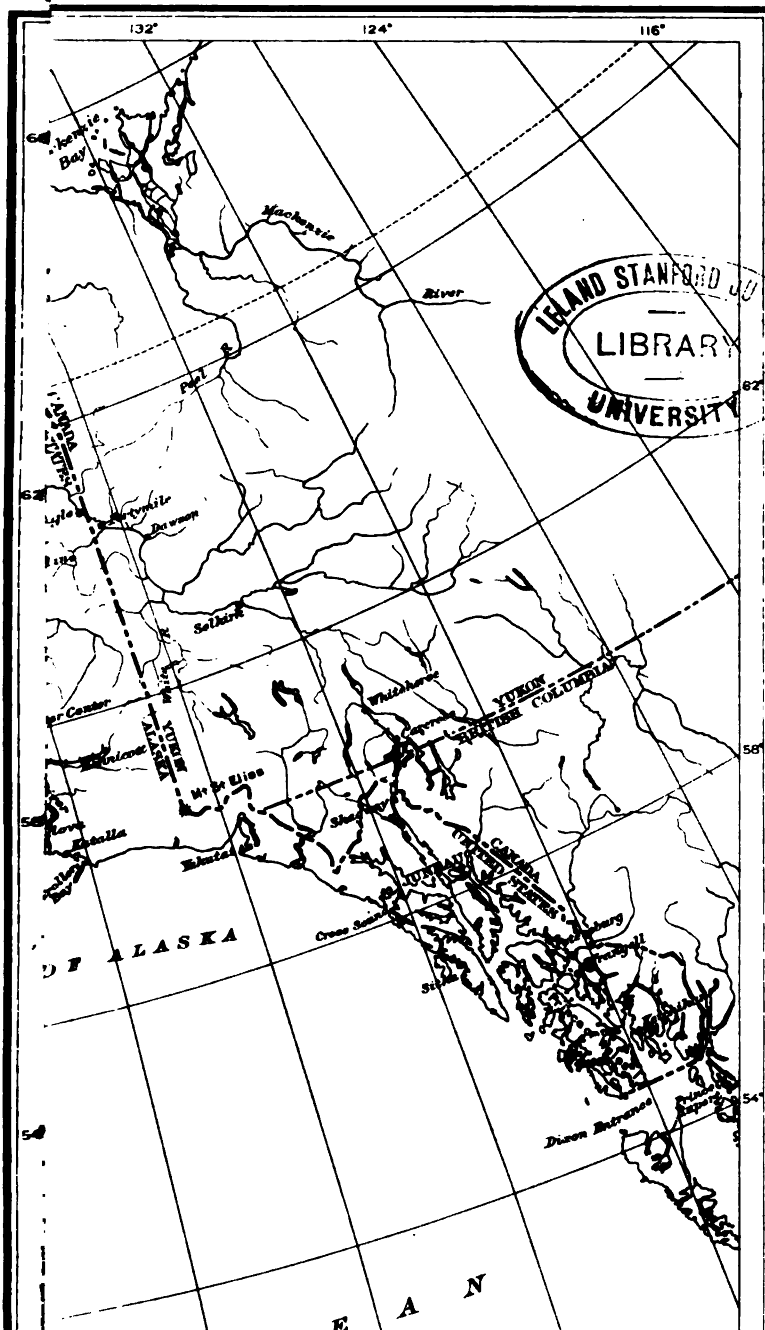
central Alaska, in about latitude 63° N., longitude 154° W., or about 500 miles above the head of deep-water navigation at Bethel and 600 miles from the mouth of the river. The prospects and the exposures described are all included within a small area near the divide between the main Kuskokwim and Nixon Fork, which is one of the larger northern tributaries of the Kuskokwim. The district has been popularly known as the "Nixon Fork country," but this name is not especially appropriate and will probably be replaced in local usage.

ACCESS AND SETTLEMENTS.

The only feasible route to the camp that is at present open in summer is that by way of the Kuskokwim, either from its mouth or from McGrath, which may be reached by an overland route from Iditarod. McGrath was the nearest permanent settlement in 1920, although there seemed to be promise that a small settlement would be established at Berry's Landing, near the forks of the Kuskokwim, about 90 miles above McGrath. (See Pl. III.) Berry's Landing is the head of ordinary navigation on the Kuskokwim; it can be reached by launches or small steamers. Although the river is probably navigable by small boats for some distance above the forks, Berry's Landing is the nearest point on the river to the lode prospects. From this landing a wagon road leads northward about 15 miles to the prospects. This road was not in good condition in 1920, being with difficulty kept passable for heavy freight wagons. It is believed, however, that a good road could be constructed on or near the position of the present road, although there are many very swampy areas which it may prove difficult to avoid or to improve. About halfway from Berry's Landing to the prospects the road leaves the flats and climbs onto solid ground on the slopes of the hills. From this point to the mines the road is in good condition. There was in 1920 no regularly scheduled navigation on the river. Small steamers and launches ascended the river with freight from Bethel whenever an ocean shipment arrived at that port, and launches went up from McGrath whenever business offered. A few travelers have made the summer journey to the camp from Ruby, and some possibly from points in the Tanana Valley, but there are no established summer trails, and the soft ground and brush make travel over a direct or random route from these points very difficult. Summer travel from these directions is consequently not to be recommended until trails are built.

In winter the district is accessible by sled routes from almost any desired direction. It lies not far north of the former winter mail route from Anchorage to Iditarod and can be easily reached from any of the settlements in the Tanana Valley.

Comparatively easy access to the district could probably be had in either summer or winter over a road built from some point on the Government railroad between Nenana and the foothills of the Alaska Range. Such a road would be about 200 miles long (see Pl. III) and would follow the foothills of the Alaska Range through the Kantishna district, past Lake Minchumina and the headwaters of the North Fork of the Kuskokwim, and would continue along the divide between Nixon Fork and the Kuskokwim. Much of the area that would be traversed is unsurveyed, but enough is known about the general character of the country to make it practically certain that a feasible



ALASKA MAP C
Edition of 1916

route for a road can be found. If a productive mining camp is established here it is believed that most of the transportation of passengers and light freight to and from the district will be over some such route as this, though heavy freight will probably always move over Kuskokwim River.

RELIEF AND DRAINAGE.

The camp is in a group of irregular rounded hills, which have no definite trend and stand in general about 1,000 feet above the forks of the Kuskokwim, or probably about 1,500 feet above sea level. The area is in one of the higher parts of the line of hills which forms the divide between Nixon Fork and the Kuskokwim. The hills in the immediate vicinity of the camp have steep but fairly smooth slopes. Cliffs, sharp peaks, and ridges of definite trend are noticeably absent. The area between the hills and the Kuskokwim is an imperfectly terraced flat having a general elevation of about 50 feet above the river. It is the customary river flat of interior Alaska and is probably formed of several terraces, but no detailed information concerning their number, attitude, and form is at hand. All the prospects thus far discovered are on the Nixon Fork side of the divide, on small creeks that flow out from the hills and meander across the broad, flat valley to join Nixon Fork, which follows a most meandering course, as indicated on the accompanying map (Pl. III). The courses of these creeks beyond the immediate vicinity of the prospects and the identity of possibly larger streams into which they may empty before reaching Nixon Fork is not known. The lack of knowledge concerning them is indicated by the names Puzzle, Mystery, Hidden, and Riddle, which have been applied to some of the creeks.

VEGETATION.

The hills and small valleys in the vicinity of the camp are covered with a fairly uniform but in general open mixed forest of spruce and birch, and on the hillsides there are fairly numerous but not very dense thickets of alders and willows. A remarkably thick coat of moss covers all the slopes. Exposures of rock or bare ground are very scarce, even along the creeks or on the tops of the highest hills. The flats along Kuskokwim River bear scattered patches of forest, which are separated by swamps and meadows. The trees include spruce, poplar, and larch, the poplar predominating except in favored places, most of them either near the river or at the base of the hills, where there are forests of spruce.

Grass grows abundantly on the hillsides and in the more open birch forests. There is also much grass on the flats, but most of it is marsh grass. The parts of the flats seen by the writer are either swampy or have been recently burned over and bear little or no useful vegetation.

ANIMALS.

The larger animals include moose, caribou, and probably both brown and black bear. All are relatively scarce, for this district lies in one of the poorer game countries of central Alaska. The reason for the scarcity of the larger game animals is not known. They have not been exterminated by hunters, for the human population, both white and native, is small, and there has been no hunting for market or for trophies. The smaller fur-bearing animals are said to be abundant. The useful birds include numerous grouse and waterfowl of various kinds.

CLIMATE.

This district is within the more rainy part of central Alaska. Summer rains are much more frequent than in the Yukon-Tanana region, but the rainfall is of course not so great as that of the coast region. No weather records are available, but the abundance of rain is indicated not only by the general observations of the inhabitants but by the dense growth of moss on the hillsides.

GEOLOGY.

The rocks exposed in the vicinity of the prospects include Paleozoic (probably Middle Devonian, though possibly Ordovician) limestone and shale, a mass of quartz monzonite which is intruded into the limestone, terrace gravel, and stream gravel. (See fig. 5.) The limestone and shale are believed to underlie a large area throughout the region and are probably cut by numerous masses of quartz monzonite that have not yet been discovered.

LIMESTONE.

The rocks in the vicinity of the lode prospects of the Kuskokwim, except the intrusive rocks and gravels, are limestones that are believed to be part of the limestone and slate which Spurr[11] has described as the "Tachatna series" (now spelled Takotna). The fact that the writer observed only limestone with little if any interbedded shale or slate in the hills near the lode prospects, whereas Spurr described the exposures in the river bank as including much shale or slate, probably means that the limestone finds its characteristic topographic expression in the peaks and ridges, which comprise almost the only exposures of bedrock away from the river. The additional fact that the exposures are few but are practically all of limestone is perhaps an indication that limestone is not areally the most extensive rock of the district.

[11] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 123, 157-159, 179, 1900.

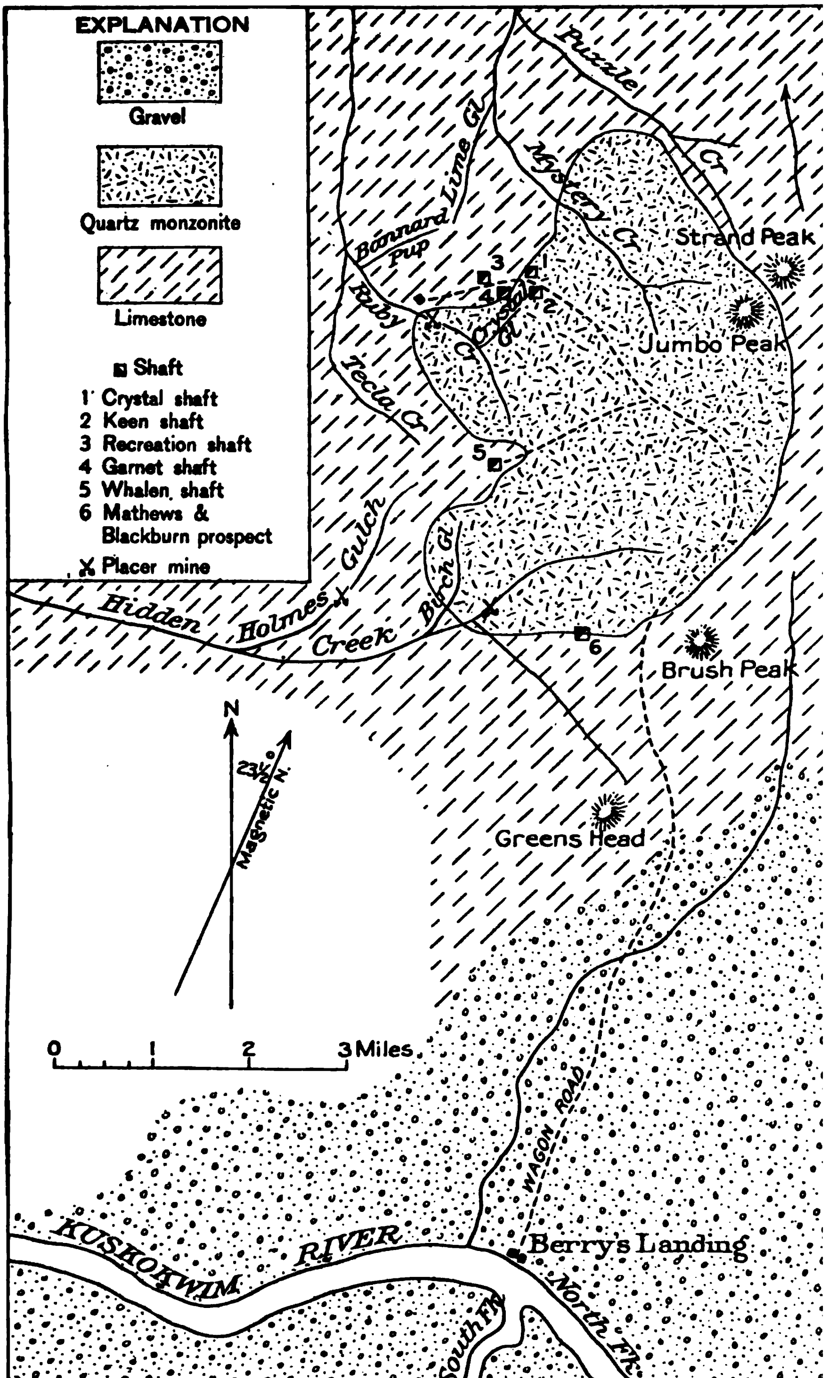


FIGURE 5.—Geologic map of Nixon Fork lode district, upper Kuskokwim basin.

The exposures noted by the writer are of fine-grained blue limestone, which is recrystallized to a moderate extent and cut by a multitude of irregular joints and by many thin seams of calcite. The bedding is obscure and possibly has been destroyed by shattering and recrystallization. No other rocks interbedded with the limestone were observed. No estimate of thickness or determination of the structure was made. Fossils were sought with considerable care, but none were found.

These limestones are believed to be the equivalent of the Takotna "series," which, as described by Spurr, includes the exposures on the north bank of the Kuskokwim between the forks and the mouth of Takotna River. The Takotna "series" was described by Spurr [12] as follows:

The Tachatna series consists of a series of gray, generally thin-bedded limestones, with limy, carbonaceous, and chloritic shales and some fine-grained arkoses. The rocks have been considerably folded and contain frequent quartz veins. They are cut by granitic dikes in rare cases. From the light-gray limestone in this series fossils have been obtained which indicate a probable Middle Devonian age for this horizon. The Tachatna series is separated from the overlying Holiknuk series, in which probable Cretaceous fossils occur, by an unconformity, while the series underlying the Tachatna was not exposed.

The Middle Devonian age of the Takotna "series" has been determined from fossils collected by Spurr at a locality on the north bank of the Kuskokwim, about halfway between the forks and the mouth of Takotna River. The following statement [13] concerning these fossils was written by Charles Schuchert:

The material submitted consists of a blackish, weather-worn limestone, containing the following corals:

Favosites, much like *F. billingsi* of the Hamilton formation.

Favosites, with smaller corallites. It may, however, be a variation of the one mentioned above.

Alveolites, with very small corallites.

Striatopora, sp. undet.

Crepidophyllum?

Stromatoporoids, two species, one having a globular and the other a ramose mode of growth.

There are no corals in this fauna pointing unmistakably to the Silurian (Upper), and since there is nothing present to disprove a Middle Devonian aspect, I assume that to be the age.

The only other Devonian locality known to me in Alaska is Kuiu Island, Saginaw Bay, in southern Alaska, south of Sitka. (See U. S. Geol. Survey Seventeenth Ann. Rept., pp. 900 and 902.) The fossils from Cape Lisburne, in north Alaska, are also all corals and appear to indicate the Upper Silurian, but there is also a possibility of their being Devonian. The few fossils gathered last summer by Mr. Brooks may also be Devonian.

It is also possible that the limestone exposed near the prospects may be the equivalent of an Ordovician limestone found near the

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[12] Spurr, J. E., op. cit., p. 179. [13] Idem, pp. 158-159.

headwaters of the North Fork of the Kuskokwim and described by Eakin.[14] This Ordovician limestone occurs at the north end of the range of hills which extends northeast from the locality herein described. The intervening area has not been traversed by geologists, and it is not known that the limestone extends through it continuously, but observations made by Eakin and by the writer from the north and south ends of the intervening belt indicate that this intervening area is probably chiefly limestone. It is therefore possible that the limestone at the prospects is continuous with the limestone near the headwaters of the Kuskokwim and is of Ordovician age instead of being continuous with the nearer Devonian limestone exposed on the banks of the river.

INTRUSIVE ROCKS.

A roughly oval area of quartz monzonite, about 3 by 5 miles in size, cuts the limestone in the vicinity of the prospects. A few small basic dikes, one of which (p. 161) is of pyroxenite, have also been intruded into both the monzonite and the limestone. The monzonite is locally known as granite and may properly be so called in popular speech, although microscopic examination shows that it differs somewhat from a true granite, being more basic and therefore intermediate in composition between granite and diorite. The monzonite of this area is very similar to the monzonite of the Iditarod and Candle Creek gold placers. It is a sodic quartz monzonite composed of quartz, andesine, albite, biotite which is partly chloritized, apatite, and zircon. It is possible that there are other masses of monzonite in the vicinity, and other igneous rocks may also be present.

GRAVELS.

The flats bordering Kuskokwim River are covered with bench gravels that extend in places for several miles back from the river. No record of the altitude of the highest benches was made, but the writer believes that the general upper limit of the well-developed benches is about 100 feet above the river. Spurr[15] records a silt bluff 100 or 150 feet high about halfway between the mouth of the East Fork and the mouth of Takotna River and notes that the silt banks between this locality and some localities well up on the South Fork do not rise more than 20 feet above the river. The writer agrees with this observation but believes that higher terraces, not cut by the river, are present in this interval. These deposits are the usual river benches of interior Alaska and call for no special description.

The small streams near the lode prospects have the customary alluvial wash, which is locally gold bearing.

[14] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 23-25, 1918.
[15] Op. cit., p. 122.

Glacial deposits are not known in the region, although much of the material in the terraces and bars of the Kuskokwim was derived from glacial deposits in and near the Alaska Range.

MINERAL RESOURCES.

GOLD LODES.

OCCURRENCE.

The gold lodes herein described lie on or near a contact between quartz monzonite ("granite") and limestone. The monzonite outcrops in a roughly elliptical area measuring about 3 by 5 miles. The west side of the monzonite has an irregular outline that may be due either to erosion along a sloping contact, to original irregularity in the shape of the monzonite mass, or to deformation. The rocks are so poorly exposed that the contact relations are not well known, but it is believed that the monzonite is intrusive into the limestone, that the western margin of the monzonite slopes westward at an angle departing appreciably and perhaps considerably from the vertical, and that the contact has been modified by faulting along lines diagonal to its original direction.

All the known ore bodies and most of the indications of mineralization have been found at or near the contact of the monzonite and the limestone, near the western margin of the monzonite, at places where the contact departs sharply from its general northerly trend. The ore does not occur in one continuous body but in several lenticular masses, none of which has yet been traced for any considerable distance. It is believed that workable ore is more likely to be found where the contact has been cut by faults or by zones in which the rocks are shattered. The ore bodies perhaps extend along the faults for considerable distances from the intrusive contact or along the contact for considerable distances from the faults.

Although the ore shows considerable differences in appearance and in richness from one prospect to another, it is probably of one general type, characterized by the presence of gold-bearing copper sulphides, which have been deeply and thoroughly weathered in most of the prospects to iron oxides and hydroxides and copper carbonates. The ore in all the prospects except the Crystal shaft is thoroughly oxidized to the extreme depth reached by the workings in August, 1920. The ore in the Crystal shaft, on the contrary, is unoxidized, even at the surface. The lack of alteration at the Crystal shaft may be due to some unexplained tightness of the fissure or to the fact that this ore body is within the monzonite, whereas most of the others are in the limestone or on the contact.

No assays of the ore have been made by the Geological Survey. A published description,[16] which is believed to be based on reliable first-hand information, says:

The ore is valuable chiefly for gold, but it carries 2 or 3 ounces of silver, and some of it contains from 2 to 8 per cent copper. * * * Several lenses of ore have been disclosed; they consist of high-grade ore—for example, 38 feet assaying $56 and 32 feet assaying $65 per ton. A large proportion of the ore assays between $30 and $35 per ton, for a full stoping width, but the ore bodies are comparatively short—for example, 40 to 60 feet.

Most of the ore seen by the writer is believed to contain not more than 2 per cent of copper. A specimen which was sent to the Geological Survey and which is said to have come from the Whalen claim contains copper and a little nickel.[17] Samples collected by the writer from the Recreation, Garnet, Whalen, and Crystal shafts, the Garnet trench, and the Mathews & Blackburn prospect were analyzed in the laboratory of the Geological Survey, and no trace of nickel was found.

Additional ore bodies may be sought not only along the contact of the limestone with the mass of monzonite but on the margins of any other monzonite areas that may be discovered in this district. The geographic and geologic province of which the known mineralized area is a part and in which similar geologic conditions may be expected and additional mineralized areas of this type may perhaps be found includes the belt of hills between Kuskowim River and Nixon Fork extending northeastward from the mouth of Takotna River for a considerable distance beyond the forks of the Kuskowim and possibly as far as the headwaters of the North Fork. Most of this area has not been examined geologically, but limestone is visible for a considerable distance from the hills near the prospects. Special search should be made in this belt for other areas of monzonite, and they should be carefully prospected, although it is not certain that they will contain valuable ores.

MINE AND PROSPECT OPENINGS.

Crystal shaft.—The Crystal shaft is near the head of Crystal Gulch, a tributary of Ruby Creek (fig. 5). It is in the monzonite not far from the limestone. The shaft was begun in January, 1919, and was sunk in the winter of 1919–20 to a depth of 65 feet. The workings, which were inaccessible at the time of the writer's visit, were made for the purpose of mining whatever ore could then be shipped at a profit. It is said that the ore body thus mined was a lens 10 by 20 by 65 feet in dimensions and that there was "6 feet of sulphides in

[16] Min. and Sci. Press, vol. 121, pp. 475–476, 1920.
[17] U. S. Geol. Survey Bull. 714, p. 93, 1921.

the bottom of the shaft." The ore is unoxidized and, as shown by specimens on the dump, consists of chalcopyrite, pyrite, and bornite in a gangue of calcite, siderite, and a zeolite, probably scolecite.

Keen shaft.—The Keen shaft is on the wagon road near the head of Crystal Gulch, about 1,000 feet east of the western border of the monzonite. It is said to have revealed a vein 4 feet wide, and material from this vein on the dump shows quartz with much yellow stain containing numerous small flakes of a grayish mineral with metallic luster (probably arsenopyrite) and a few small cubes of pyrite.

Recreation shaft.—The Recreation shaft is near the wagon road on the hillside northeast of Ruby Creek. It is in the limestone about 600 feet west of the margin of the monzonite. A shaft 50 feet deep with a drift 35 feet long exposes a vein having a maximum thickness of 6 feet. The vein has been traced by surface cuts for about 200 feet. The ore is thoroughly oxidized and shows in thin section iron oxides and hydroxides, quartz, chlorite, which is in part spherulitic, malachite, probably some azurite, and a little apatite. The specimens show much dark-green and some blue stain, probably derived from copper minerals. No sulphides or metallic minerals were seen.

Garnet shaft.—The Garnet shaft is south of the wagon road near the head of Crystal Gulch. It is in limestone, about 100 feet from the outcrop of the monzonite, but masses of monzonite show in the lower workings. The shaft was 76 feet deep when visited, and there was about 70 feet of drift. At the surface the ore is the full width of the shaft, which does not show the walls. At the bottom of the shaft the vein is not more than 4 feet wide. The ore, which is thoroughly oxidized, consists of chloritic material, iron ores, and quartz with many thin films and small masses of malachite and azurite.

Whalen shaft.—The Whalen shaft is on the divide between Ruby and Hidden creeks. At the end of August, 1920, it was 100 feet deep, and there was 160 feet of drift on the 40-foot level. Crosscuts on the 40-foot level show 32 feet of ore reported to average $68 per ton in gold. The vein is in limestone not far from the monzonite, and at the south end of the workings it lies very close to the monzonite. The ore, which is thoroughly oxidized even in the deepest workings, consists of chloritic material, iron ores, and quartz, containing many small masses of copper carbonates and a few small masses of chalcopyrite or pyrite.

Garnet trench.—The Garnet trench is on the contact between the monzonite and limestone, south of Mystery Creek and near the northeast corner of the Southern Cross claim. The ore consists chiefly of garnet containing many thin films and small masses of malachite and azurite. The thin section shows, in addition to garnet,

augite, a little sericitized plagioclase, apatite, epidote, and chloritic material.

Twin shafts.—The Twin shafts are near the center of the Southern Cross claim. They are in an oxidized zone on the contact of a fine-grained porphyry dike intrusive into limestone. The ore was so much decomposed that no microscopic study or determination of the constituent minerals was possible. It is said to carry about $10 worth of gold per ton.

Mathews & Blackburn prospect.—The Mathews & Blackburn prospect is in the valley of Hidden Creek, near the south end of the area of monzonite. Only a small, shallow excavation had been made at the time of the writer's visit, and no well-defined ore body had been exposed. The prospect is situated on the outcrop of a basic dike intrusive into limestone, near the margin of the main mass of monzonite. The dike is of pyroxenite and is composed of augite, which is the chief constituent, magnetite, which also is present in considerable amount, melilite, a green garnet that is probably melanite, iron oxides, calcite, chloritic material, and copper carbonates.

GOLD PLACERS.

The Mathews & Blackburn placer mine is on Hidden Creek, just inside the area of the monzonite. It was worked on a small scale by shoveling in from an open cut. The pay gravel is said to be 75 to 125 feet wide. and it has been shoveled in to a depth of about 4 feet.

The O'Malley & Walden placer mine is on Ruby Creek near the contact of the monzonite and limestone. It is worked by drifting.

The Griffin & Whalen placer mine, on claim "No. 1 above," on Holmes Gulch, is in the limestone about a mile west of the margin of the monzonite. It was worked by sluicing in the early part of the summer of 1920, as in previous years.

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METALLIFEROUS LODES IN SOUTHERN SEWARD PENINSULA.

By S. H. Cathcart.

INTRODUCTION.

The value of the total mineral output of Seward Peninsula is about $81,000,000, of which over $80,000,000 is the value of the gold won from placer mines. Lode prospecting began soon after placer mines were developed[1] and has been continued in a more or less desultory manner through a period of 20 years, but thus far the attempts to open up lode mines have met with but little success. Little bedrock work has been done since 1917, when the effects of the World War began to be felt, and since then the suspension of the requirement for annual assessment work has still further decreased the prospecting of lode claims. In 1915 and 1916, owing to the war demands, a temporary stimulus was given to the mining of stibnite-bearing lodes, but it soon subsided. The Big Hurrah quartz mine is the only lode-gold producer that was opened up on any considerable scale, and this mine was operated only from 1903 to 1908 and then not continuously. Within the last few years underground work has been done at the Lost River tin mine, the Kougarok silver-lead property, and the gold lodes near Bluff, but elsewhere lode development has been almost negligible. There are now no productive lode mines in the region under discussion; only a few have produced in the past, and the output from those few has been small.

In the area of the York Mountains the relation of the mineralization to the geology has been pretty well established.[2] Tin, tungsten, antimony, copper, and lead have been discovered and are known to be closely related to granite bosses and porphyry dikes that intrude the limestone and slates. For the rest of the peninsula no such relation has been determined. A possible exception is the platinum recovered from the placers of Dime Creek. Basic igneous rocks occur in the vicinity of these placers, and although platinum has not been determined as a constituent of those rocks it is believed to have been derived from them.

In the absence of such well-defined genetic relations for the mineralization of most of the peninsula, it was deemed desirable to ascer-

[1] An exception to this statement is the silver-lead deposit at Omalik in the Fish River basin, which was opened up and from which some ore was shipped as early as 1881.

[2] Steidtmann, Edward, and Cathcart, S. H., The geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. — (in preparation).

tain the conditions which have led to a very wide distribution of metallic minerals throughout the country rock, especially the conditions which have resulted in concentrations of gold rich enough to be reflected in scattered placer deposits but which have not produced gold lodes of notable promise.

The writer undertook to determine, so far as the physical conditions permitted, the geologic relations of the bedrock occurrence of metallic minerals in this region. It was believed that such studies might help the prospector by determining the geologic conditions under which the metalliferous lodes were formed. Field work was begun on July 3 and continued until September 19, 1920. During this time most of the lodes of the peninsula in the area south of the mountains, between Council on the east and Cripple River on the west, were visited and the country rock in the vicinity of the richest placers was studied in an attempt to determine something more concerning the relations that exist between the mineralization of the region and the geology. In all 110 prospects were examined, and the ores, where available, were studied. The prospects show considerable variety in mineralization. Iron, bismuth, tungsten, gold, copper, lead, zinc, graphite, and antimony have been found in bedrock, and mercury is known in the placers.

The investigation was originally planned to be continued through several years, with the hope of not only determining the genesis of the ores but also correlating the many geologic formations found in Seward Peninsula. As for the present the investigation has been suspended, it seems desirable to record the provisional conclusions reached during the first season of field work.

This paper outlines certain features of the mineralization that were observed. It does not describe in detail all the prospects examined, nor discuss in more than a general way the mineralization of other important districts which were not visited. Descriptions of the geology and mineral deposits of the peninsula are contained in previous reports published by the United States Geological Survey, a list of which follows.

Preliminary report on the Cape Nome gold region, Alaska, with maps and illustrations, by F. C. Schrader and A. H. Brooks: Special Pub., 56 pp., 19 pls., 1900.

Reconnaissance in the Cape Nome and Norton Bay regions, Alaska, in 1900 (A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, assisted by G. B. Richardson and A. J. Collier; A reconnaissance in the Norton Bay region, Alaska, in 1900, by W. C. Mendenhall): Special Pub., 222 pp., 23 pls., 1901.

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GEOLOGY.

OUTLINE.

The foregoing list of publications indicates the large number of geologic investigations that have been made on Seward Peninsula. The Geological Survey has published reconnaissance geologic maps (scale 1:250,000) of nearly the entire region (20,000 square miles) and detailed maps (scale 1:62,500) of certain important districts.[3] These surveys and investigations have been made by a score of geologists during a period of more than 20 years. Each new investigation has added many additional facts bearing on the geology and the occurrence of mineral deposits. As yet there has been no adequate summary of this large mass of material and no correlation of the many formations to which the rocks have been assigned. To the end that a better understanding may be had of the relation between the ore deposits, to be here described, and the general geology of the region, the following provisional statement on the stratigraphy of Seward Peninsula as a whole is here quoted from an unpublished manuscript by A. H. Brooks:

> The bedrock of Seward Peninsula includes many sedimentary formations, ranging in age from pre-Ordovician to middle Carboniferous (Pennsylvanian). There are also some Upper Cretaceous sediments, as well as extensive lava sheets, chiefly of Quaternary age but in part possibly older, in the eastern part of the peninsula. In much the larger part of the peninsula intrusive rocks are not abundant, but in the Kigluaik, Bendeleben, and Darby mountains there are extensive stocks of granite rocks with

[3] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, pls. 6-7, 1910. Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pls. 3-4, 1913.

some dikes. There are also a number of granitic stocks, with which porphyry dikes are associated, in the York district. A few isolated stocks of granite occur in other parts of the peninsula. There are also local occurrences of pegmatitic, gabbroid, and diabasic intrusives.

All investigators of this field have recognized two distinct systems of structure, one trending about north and the other about east, but there is diversity of opinion as to which is the older. The Cretaceous rocks of the eastern part of the field are involved in the northerly folds. As these are the youngest consolidated rocks, it is evident that their deformation occurred during the most recent period of crustal disturbance. There is, however, some evidence of folding in late Paleozoic time, which produced structural features trending north. It is therefore possible that the post-Cretaceous (Eocene?) folds followed the structure of older Paleozoic time. The east-west folding is probably to be correlated with the dominating structural features of the Arctic Mountain system of northern Alaska and Siberia, which trend approximately east. This folding was certainly earlier than Upper Cretaceous, probably pre-Cretaceous, and certainly not earlier than Middle Jurassic. There is evidence that there has also been some later movements along these older east-west folds. As the intrusions were no doubt in a general way contemporaneous with the folding, and as in turn some if not all of the mineralization was genetically related to the intrusions, the tectonic history of the region is not without economic interest.

The bedrock of most of the gold-bearing areas of Seward Peninsula, especially in its southern part, consists of feldspathic and mica schists locally interbedded with metamorphic limestones that in places broaden out into considerable belts. The schist areas are also in places broken by wide belts of both massive and schistose greenstones and also by narrower belts of slates and quartzites. These formations are without doubt Paleozoic, and there is much evidence that they are younger than Silurian. They may be tentatively assigned to the Devonian or Carboniferous. The multiplicity of formation names in the many reports dealing with the geology of Seward Peninsula has caused much confusion in the minds of those not personally familiar with the region, hence it seems desirable to present at least a provisional correlation of the many formations that have been described, beginning with what are believed to be the oldest rocks of the peninsula.

Pre-Ordovician.—Dark slates and phyllites, locally graphitic, with some thin beds of limestone. These rocks have been definitely recognized only in the western part of the peninsula.

Ordovician with some Silurian.—Massive arenaceous limestone, locally crystalline. Typically developed in the western part of the peninsula, where these rocks are termed Port Clarence limestone. They carry Ordovician and Silurian fossils and, as mapped, some of Pennsylvanian age. Paleozoic limestone, with which are associated some dolomite and slate, is widely distributed in Seward Peninsula. For many of these rocks no definite age assignment is possible on the basis of the facts now in hand. The limestone beds at some localities carry Silurian fossils (in dolomite), some include Middle Devonian fossils, some are undoubtedly of Pennsylvanian age, and some possibly Ordovician.

Devonian (?).—Feldspathic, micaceous, siliceous, chloritic, and graphitic schists, with some beds of limestone, are very widely distributed over the region. The age of most of them seems to be pretty definitely later than Silurian, and there is some evidence that they are immediately succeeded by Pennsylvanian limestone. These rocks are provisionally assigned to the Devonian. In this group are included the Nome, Solomon, Kuzitrin, and Tigaraha schists and the schist of the Kigluaik group. It appears that the lower part of this series (Kuzitrin, Kigluaik, Tigaraha) is siliceous and the upper part calcareous. Most of the gold deposits of the peninsula have been found in association with the more calcareous members of this group of formations.

Carboniferous limestone.—Massive light-blue and white crystalline limestone. At Cape Mountain (Bering Strait) Pennsylvanian fossils have been found in this forma-

tion. The Sowik limestone of the Solomon region and the limestones overlying the Nome group are believed to belong to this formation.

Carboniferous.—Succeeding the supposed Pennsylvanian limestone in the Solomon and Casadepaga region are formations made up of black quartzose slates and schists not definitely recognized elsewhere in the peninsula. These have been termed the Hurrah slate and Puckmummie schist.

Carboniferous (?).—Greenstones are widely distributed in the peninsula, especially in the southern part. They occur chiefly as stocks, dikes, and sills, most of which have been rendered schistose. Their age is not definitely known, but they appear to be the youngest Paleozoic rocks of the region. The Casadepaga schist (chloritic) has been correlated with these rocks.

Intrusives.—Granitic and allied intrusive rocks occur as stocks and dikes in certain parts of the peninsula. They intrude the youngest of the known Paleozoic rocks and are for the most part Mesozoic or younger. Some of these rocks are sheared and gneissoid, as in the Kigluaik Mountains; others are massive, as those of the York district, where the granitic intrusives are accompanied by porphyry dikes. In the York district the mineralization is genetically related to the intrusives, and this is probably also true in some other districts.

There is good reason to believe that there was more than one period of intrusion. In the region east of Norton Bay mineralized rock accompanies granitic intrusives which traverse Upper Cretaceous beds and are probably of Eocene age. The opinion is ventured that the massive intrusives of the York district and possibly of some other parts of the peninsula are of Eocene age and were injected at the time of the latest period of deformation, which produced north-south folds. If this is true the other intrusives can logically be correlated with the older Jurassic (?) folding. So far as is now determined, this earlier period of intrusion was not accompanied by any very definite epoch of mineralization—at least, no evidence of mineralization has been found in association with the granites of the Kigluaik Mountains, which are believed to belong to the earlier epoch of intrusion.

Quaternary.—The Quaternary deposits consist principally of sand and gravel, with locally some small glacial moraines. During the Quaternary period there were poured out some extensive lava flows, which in certain places (Fairhaven and Kougarok districts) cover gravel deposits. In the Quaternary system also fall the terrace and ancient sea beach deposits that are especially well developed in the Nome and Solomon regions. Some of the lavas of the eastern part of the peninsula are probably pre-Quaternary.

COUNTRY ROCK.

The rocks of the area visited are nearly all metamorphosed sediments. Granitic intrusives are plentiful in the Kigluaik and Bendeleben mountains, north and northeast of Nome, but except for the granite of Cape Nome and of several smaller areas in the vicinity of Stewart River and Dickens Creek they are not known to be exposed in the area under consideration. Greenstone sills, stocks, and dikes are numerous but do not appear to have produced any mineralization. In fact, areas in which greenstones are abundant appear to be unfavorable to the occurrence of gold.

The metamorphic series consists mainly of schist but includes considerable limestone and some black slate. Chlorite schist is by far the most common type. It is usually siliceous, but calcitic varieties are common. Chlorite may be present almost to the exclusion of mica or may be only accessory to mica. The chlorite varieties

are green; the micaceous varieties gray. The mica schists consist chiefly of muscovite and are highly siliceous. Feldspar schists are common in some parts of the area. The feldspar (albite) occurs in small crystals, together with chlorite and quartz, and the rock is not always easily distinguished from the chloritic types. Graphitic schists are present but are abundant only in small areas. The rocks are made up chiefly of quartz, massive and brittle, through which graphite is finely disseminated and with it a little muscovite. The schists taken as a whole are chloritic and siliceous. Graphitic, feldspathic, calcareous, and micaceous varieties are common but are subordinate to the general type. Accessory minerals, including biotite, are present in much of the rock, but these are nowhere conspicuous. The above-described schists belong principally to what has been called the Nome group.

Black slate is best developed in the Solomon region (Hurrah slate). It is a very siliceous rock, black, brittle, with good cleavage, and composed chiefly of quartz, with graphite, and here and there a little sericite. Lithologically similar types occur in the Council, Iron Creek, and Nome regions, but the fine slaty qualities are best developed in the Solomon region.

Limestone is an important constituent of the series. It occurs in thin beds generally not more than 50 feet thick and commonly only 5 feet thick throughout the schist series. It may occur as an occasional layer of limestone interbedded with schist, or it may form half of the section. As heavy-bedded limestone including thin beds of schist, it is most conspicuous and covers a considerable area. The beds are light gray or blue-gray to dark blue, are everywhere marmarized, and are in many places schistose.

STRUCTURE.

The structure of the rocks of the area is complex. Faulting has occurred in all the formations. Close folding is not unusual in the limestones and is common in the schists. The details of the structure are not well known. Two periods of deformation are recognizable. The axis of one set of folds strikes in general north; that of the other set east. The easterly folds are best developed in the vicinity of Kigluaik and Bendeleben mountains, where they are the prevailing structural features. Although they can be recognized throughout the area, they are elsewhere subordinate to the northerly folds. The areas of most intense deformation are the Nome and Solomon regions. Smith[4] has described in detail the structure of the Solomon and Casadepaga quadrangles, which may be considered as best illustrating the complicated geology that is rather characteristic of the peninsula as a whole.

[4] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, pp. 111-120, 1910.

MINERALIZATION.

ROCK OPENINGS.

The distribution and occurrence of the mineral deposits of a region are largely dependent upon the openings that were available at the time the mineral-bearing solutions were introduced. The extreme irregularity of many of the lodes of Seward Peninsula and the disseminated character of the mineralization are perhaps best explained by considering the stratigraphy of the metamorphic series, the contrast between the physical properties of the rocks of that series, the order of their succession, and the way in which they behaved when subjected to deforming forces.

Viewed in a general way the metamorphic series, principally mapped as the Nome group, is composed essentially of schist and limestone. at is not possible to give a measured section showing the relative proportions of the two rock types and their relation to each other, as the structure is complicated by intense folding and a great deal of faulting. Horizons are not distinguishable by lithologic data, and the limestones are fossiliferous in but few localities. Metamorphosed and unmetamorphosed greenstones add further complications, so that it is impracticable to subdivide the series other than into two parts, one predominantly schist, the other predominantly limestone.

The lower part consists chiefly of schist with interbedded limestone. The limestone beds range in thickness from less than 1 foot to perhaps 100 feet. Beds 5 to 20 feet thick are the most common. Few limestone beds of 20 feet or more do not contain one or several thin zones of schist. Not uncommonly the limestone and schist are about equally abundant and of about the same thickness. The most pronounced limestone zones include 20 to 30 per cent of schist interbedded with the limestone, and the most pronounced schist zones contain thin beds of limestone. Almost any ratio of limestone to schist or of schist to limestone can be seen in different parts of the area. The limestone is usually coarsely crystalline and fairly massive. Thin-bedded platy types and schistose phases also occur. The various types of schist that occur in the group have been described. They range from soft calcareous and highly chloritic varieties to dense brittle siliceous varieties. Slates are conspicuous in some parts of the area, especially in the Solomon and Iron Creek districts.

The limestone division of the Nome group, though chiefly limestone, includes many thin beds of schist ranging from 1 foot to 50 feet or more in thickness. The limestone is recrystallized and on the whole fairly massive, but zones of thin-bedded platy and schistose types are common. The contact between the two divisions is not sharp. In the limestone division schist is relatively most abundant at the

base, and in the schist division limestone is relatively most abundant at the top.

The succession of limestone and schist is an extremely heterogeneous group. All degrees of so-called competency are represented not only among individual members of the group but among beds at various horizons throughout the group as a whole. The competent beds are the limestones, slates, and quartzose schists, and their competency within any zone is dependent upon their proportion and disposition relative to the less competent micaceous, chloritic, and calcareous members of the group.

A part of the gold mineralization is known to have occurred before the deformation of the series that produced most of the schist. Probably the larger part of the gold and apparently all the other valuable minerals were introduced later than the period of greatest metamorphism. The openings into which these later minerals were introduced resulted from folding or faulting of the heterogeneous series just described. All the later movements were not of the same age nor of the same intensity. Neither was all the later mineralization of the same age, but all the later openings were developed under similar conditions in a series of rocks whose physical characteristics were probably not much different at the different stages of deformation. The same principle, therefore, probably governed the formation of the rock openings in all the later periods of deformation.

As pointed out by Brooks [5] the most widespread effect of folding was to cause an adjustment within the series which to a large extent took the form of shearing at the contact of the so-called competent and incompetent beds. The physical properties of the rocks, other than their competency or resistance to deformation, were also important, especially those of the limestone. The uniform bedding planes of the limestone acted as original well-defined surfaces of weakness, so that when shearing forces were applied movement took place along these surfaces. These contact and bedding shear zones resulted in many poorly defined fissures which were distributed throughout the schist-limestone and limestone-schist divisions. Though the fissures were commonly not of great width and few of them are occupied by well-defined, massive veins, they permitted the infiltration of gold-bearing quartz and sulphide solutions and contain the quartz stringers so generally distributed through the area.

The controlling influence during deformation has been in large part the limestone and other competent members of the series, but exceptions to the localization of the fissures along the limestone contacts are so numerous that they require further explanation. Where the limestone beds are thick, as compared with the schists, the openings

[5] Brooks, A. H., U. S. Geol. Survey Bull. 328, p. 122, 1908.

seem to be closely confined to the immediate contact. Where the width of the schist zones is greater, adjustment within the relatively plastic schist beds has been effected by close folding, which has given rise to shears within the schist body and a general shattering of it. As the width of the schist zones increases, the fissuring becomes less closely confined to the contacts and more independent of the limestone. The most pronounced shear zones occur in bodies of schist several hundred feet in thickness in which competent beds are reduced to a minimum, but even here the action of the competent beds as the controlling factor during adjustment is recognizable. An especially favorable horizon for fissures formed by such shearing is at or near the junction of the main limestone division of the group and the underlying schist division.

Other fissures that cut the schist and the limestone are either not related to fissures that were produced by shearing or represent the extreme product of the deformation. A certain amount of deformation could be accommodated by the adjustment of the beds of such series as have been described, but if the deforming forces continued to act the beds would break. Fissures thus produced are the cleanest cut and most continuous observed and are occupied by the largest veins known in the area. Of the fissures in the schist even the cleanest cut show extreme irregularity. The physical properties of the schist did not permit it to fracture along sharp, well-defined planes. The fissures follow sinuous courses along both the strike and the dip, and horizontal movement along these sinuous lines has given to the veins which now occupy the fissures their habits of pinch and swell.

Only a few veins of considerable size fill fissures in the limestone division. The physical properties of the limestone cause it to break more evenly than the schist, and the veins in limestone are more uniform than those in schist. Any irregularities seem to be due to the division of the beds into blocks by joint planes and to unequal movement of the individual blocks, which resulted in straight-line reentrants and cavernous openings in the fissure walls. The joint systems and bedding planes in the limestone are the openings most commonly filled by later solutions.

The black slate member of the series is best developed in the Solomon region. It covers a very small area but is exceptional among the rocks of the series in the way in which it has fissured. It is a dense siliceous, uniform-textured rock which has fractured along clean-cut lines. The veins of Big Hurrah Creek occur in this formation and are the best defined and most regular of the veins known in the region. The contrast between the fracturing qualities of this division of the Nome group and those of the schist affords a good explanation why most of the veins of Seward Peninsula have proved so irregular and discouraging to prospectors.

TYPES OF DEPOSITS.

In this region concentrations of mineralization, especially of gold mineralization, are only relative. Dissemination is the rule. The concentrated deposits may be classed as veins and shear zones.

Veins.—Although the veins of Seward Peninsula have not shown great promise and have proved a source of discouragement to prospectors, because of their lack of continuity and the erratic distribution of the minerals which they contain, they are important in a study of the general mineralization of the region. They are known to be one of the sources if not the chief source of the placer gold. In addition to the original gold content of the veins, gold-bearing sulphides of a later period of mineralization have in many places followed the same fissures as the veins and fill fractures in the vein quartz and impregnate the schist of the vein walls. So far as known the original sulphide content of the veins was small.

Smith [6] has classified the veins as older quartz veins, newer quartz veins, and calcite veins. The calcite veins are abundant in both schist and limestone but especially in the limestone. Usually they occur as thin stringers and have attracted little attention as carriers of valuable mineral, but on Snow Gulch and Dry Creek, north of Nome, a number of tunnels have been driven on calcite veins that contain a little gold. The importance of the veins of this type is probably negligible.

The older quartz veins are those that antedated the period of extreme deformation and metamorphism in which the schists of the region were formed. Throughout the schist occur lenses and masses of quartz, some of which suggest by their outline that they are derived from or are deformed remnants of veins that were contained in the sediments at the time of their metamorphism. Smith [7] has noted that some of this quartz has had a different origin, being the result of the decomposition of silicate minerals during metamorphism. The quartz of the older veins is completely recrystallized, and nothing concerning the earlier history of their mineralization can be determined. Some of these veins are known to carry gold, but their very irregular occurrence eliminates them as prospective lodes.

The older veins are usually inconspicuous, and it is the later veins which are usually observed and to which prospecting has been largely confined. The later veins are not all of one period, but subdivision according to age is not possible. At the Big Hurrah mine, where veins of this type are well developed, smaller veinlets of several ages can be recognized, and veinlets of later quartz cut the quartz of the main veins. A further indication of the repeated or continued injection of quartz is seen in the ribbon rock at this locality. The

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[6] Smith, P. S., op. cit. (Bull. 433), p. 90.
[7] Idem.

veins can be subdivided on the basis of accessory gangue constituents into quartz, quartz-feldspar, and quartz-calcite veins. They cut all the rocks of the series; they may be parallel to the bedding and schistosity or may cut them. They range in size from stringers less than an inch to veins several feet in width, but most of them are less than 6 inches wide. They are generally not traceable for more than a few hundred feet along the strike, and whatever their width, they are characterized by repeated and abrupt pinch and swell and irregularity of strike and dip.

The quartz of the veins is commonly white, clear, and vitreous and is stained by iron oxide on the fractured surfaces. Comb structure that shows several periods of vein growth is not unusual. The veins are characteristically of open texture, and the openings are usually cavities into which clear quartz crystals that show excellent terminations project. Some veinlets that cut schist are less than a quarter of an inch wide and show the open texture distinctly.

Where calcite occurs as an accessory constituent of the vein, it is commonly concentrated in areas through the quartz. Locally both quartz and calcite are present in about equal amounts, but usually the calcite crystallizes by itself in well-formed rhombohedrons. It may be white or stained yellow by iron oxide. Where tested it was nonmagnesian.

The feldspar type of vein is best known in the Nome area. A few of these veins occur in the Solomon area but are not conspicuous. The feldspar is everywhere of a plagioclase variety. Albite and oligoclase were about equally abundant in the thin sections examined. The feldspar occurs both disseminated through the quartz and segregated in small nests. It was nowhere seen to be present in any considerable quantity.

Sulphides of contemporaneous origin with the quartz occur in some of the veins. Pyrite is most common, but arsenopyrite and chalcopyrite have also been noted. Most of the sulphide is, however, safely assignable to a later period of mineralization, as it is usually seen to occur as veinlets in the quartz or in openings in the vein. Stibnite, arsenopyrite, and pyrite are the most abundant of the later sulphides. Galena, chalcopyrite, pyrrhotite, and bismuthinite are also known. Scheelite is a constituent of the veins in several localities, and from the general distribution of this mineral in the placers it is thought to be rather common and perhaps a minor constituent of the veins.

Shear zones.—Shear zones are exceedingly common, both in schist and in limestone. Most of the shearing, because of its very general distribution, did not cause concentration of the mineralization but rather the opposite. However, a type of shear zone is recognized in which there was considerable concentration and which may prove

to be an important factor in determining the source of the placer gold. The zones of this type occur in schist, and many of them contain very little quartz; consequently they are soft and easily concealed by talus and moss. It can not be said how abundant they are, or what their distribution may be. They are very prominent in the Snake River drainage basin, and they are probably much more numerous than they appear to be, as their exposure is largely fortuitous. Stibnite, gold, and scheelite are present in these zones. The best-defined examples were noted at the head of Waterfall Creek, on the Christophosen property; near the head of Goldbottom Creek, in the California quartz lode; on Boulder Creek, in the Boulder lode; on Rock Creek, at Sophie Gulch; in a small gulch just west of Snow Gulch, tributary to Glacier Creek; in New Years Gulch, a tributary of Anvil Creek; and opposite the mouth of Specimen Gulch, on the northwest bank of Anvil Creek. Possibly certain hematitic schists that occur on Dexter and Dry creeks belong to this class of deposits, but they do not seem to be typical. (See fig. 18.)

These zones are characterized by disseminated sulphides. In some of them quartz is plentiful, but it is older than the sulphides. Comparatively little quartz seems to have accompanied the later mineralization. Where these zones are opened by mining operations fault planes are seen to cut the schist. The weathered outcrops are iron stained, and the soft, decomposed schist will pan gold and on assay shows a low gold content. The width of the zones is not well defined, for the mineralization gradually diminished with increasing distance from the faults. Where determinable, arsenopyrite is the most abundant sulphide impregnating the schist of these zones. Pyrite is also plentiful. Stibnite occurs at the Waterfall, Rock, and Anvil creek localities, but it is not known to be contemporaneous with the arsenopyrite. Scheelite has been mined from the zone on Sophie Gulch, but at this locality quartz veinlets are numerous and at least part of the scheelite occurs as a contemporaneous constituent of the veins.

As these zones carry gold, even if their content is too low to class them as commercial ore bodies, their importance as feeders for the rich placers of the district is evident. The width of many of them is measured in scores of feet, and in some localities they are said to have been traced for several thousand feet. As known, they represent rather good-sized bodies of low-grade ore, or rather mineralized rock.

Contact shearing and shearing within the limestone has resulted in concentrations of argentiferous galena and of copper sulphides.

At the contact of many of the massive limestone beds which occur throughout the schist division there is evidence of intense deformation. The limestone has been rendered schistose, and the schistose

limestone grades into calcareous schist which in all probability has been derived from the limestone and represents the extreme phase of metamorphism. The limestone is in many places closely folded and contorted along the contact. Galena and sphalerite have been introduced along these horizons in several localities, and replacement ore bodies have been formed in the limestone and schist. The only deposit of this kind known within the area described occurs on Kruzgamepa River near the mouth of Iron Creek (p. 210). The ore here occurs as lenticular bodies in the schist and consists of galena and sphalerite in a gangue of quartz and calcite. On Kugruk River, near the mouth of Independence Creek, a deposit of lead-silver ore is being explored. The locality has not been visited by a member of the Geological Survey, but from descriptions it is understood to be a deposit of this type. At Omalik, in the Fish River basin, a similar deposit of lead-silver ore has been known for many years.[8]

At Iron Creek (p. 208) and Copper Mountain (p. 217) quartz carrying copper sulphides has been introduced along shear zones that have followed the bedding planes in the limestone, and the limestone has been replaced by silica. All the concentrations of copper minerals known in the area occur in deposits of this type.

Many of the relative concentrations in veins and mineralized shear zones grade imperceptibly into slightly mineralized country rock. Sulphides, chiefly pyrite, occur everywhere throughout the schist and slate of the Nome group and at many places in the limestone. Hardly a weathered specimen of schist can be found that is not specked with iron oxide, and thin sections show decomposed sulphide in every specimen examined. The schist as a whole is well mineralized. In the limestone the sulphides are less plentiful, but at its contact with schist and also adjacent to surfaces of movement within the limestone itself sulphides are almost always recognizable. Concentrations are frequently seen in the schist along the limestone-schist contact, occurring as tiny veinlets that cut the schist where it has suffered considerable distortion, coating fissures in the schist and coating the wall rock of quartz veinlets. It is not definitely known that the disseminated pyrite contains gold, but gold occurs chemically or mechanically combined with sulphides in some of the lodes of the area, and it is very probable that a part of the placer gold may have its origin in the disseminated sulphides.

Quartz veinlets from a fraction of an inch up to several inches in width occur in the schist in great numbers. They are nonpersistent, variable in width, and irregular in strike and dip. They appear to be almost nowhere concentrated to the point of forming a stringer lode. Such concentrations as occur are not sufficient

[8] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula: U. S. Geol. Survey Bull. 449, pp. 130-133, 1911.

to remove them from the class of disseminated deposits. The veinlets carry native gold. Stringers a quarter of an inch in width contain small nuggets. Free gold disseminated through the schists is not known to occur.

RELATION OF GOLD TO IGNEOUS ROCKS.

Brooks [9] has described the gold lodes of Seward Peninsula as deposits differing from the lodes of other parts of Alaska in that they show no genetic relation to intrusive rocks. Smith [10] cites the presence of tourmaline in many of the rocks as evidence that granitic intrusives which are not exposed may underlie the gold-producing areas and also correlates some of the later quartz veins with the intrusion of the granitic rocks of the Kigluaik Mountains. An examination of the geologic map, which shows a belt of granitic intrusives in the area of the Kigluaik Mountains, one prominent area of granitic rock at Cape Nome, and a few small isolated bosses as far south as Stewart River, suggests that the region between the mountains and the coast may be underlain by intrusive rocks.

Another criterion that may have some significance is the character of some of the later quartz veins, which are of the quartz-feldspar variety. In the Fortymile district Spurr [11] found similar veins and could trace the transition from granite to aplite to pegmatite to quartz-feldspar veins, and finally to quartz veins without feldspar. This evidence suggests that the veins of the Nome region especially have been derived from a granitic rock but represent a product a considerable distance removed from its source.

Another feature which suggests that the mineralization is related to a granitic rock is the widespread occurrence of scheelite in the placers. Scheelite occurs as a constituent of the quartz veins and is associated with the arsenopyrite. An analysis of the descriptions of 50 tungsten deposits, which include the most productive deposits of the world, indicate that some of their outstanding features are as follows: (*a*) The composition of the intrusive from which they are derived is usually that of a granite, although the deposits may be associated with rocks as basic as diorite; (*b*) the deposits may occur in the granite but usually occur in the country rock and have considerable ability to migrate from their source; (*c*) the traveling ability varies with the mineral. Scheelite is more likely to occur at a distance from the intrusive rock than any other tungsten mineral.

In the Kigluaik Mountains the granite is intruded almost entirely as sills and dikes. The few bodies of granite penetrating the Nome

[9] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, p. 70, 1911.
[10] Smith, P. S., op. cit. (Bull. 433), pp. 132–133.
[11] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 147, 291, 1896.

group south of the mountains are bosses, and the rocks are badly sheared. At one locality on Stewart River there is a granite which is so highly sheared as to be decidedly schistose, and its origin is not easily recognizable. It is possible that bosses and sills of granitic rock that have been converted to schist occur throughout the highly metamorphosed schists. Schists derived from igneous rocks have not been identified, however, and it is probable that if they are present the alteration has gone so far that they are beyond recognition.

It is not enough to say that the granite known elsewhere on the peninsula underlies the areas here discussed or that it may have been present and is now metamorphosed beyond recognition, for where the granite is known—in the York district and in the Kigluaik Mountains, for instance—it has not produced auriferous mineralization but deposits of tin, tungsten, and lead. It should be noted however, as suggested by Brooks (p. 168), that there may have been more than one period of granitic intrusion. Most of the gold deposits of Alaska are related to dioritic rocks. Diorite occurs at Cape Darby,[12] and andesite, quartz diorite, and monzonite occur in the Fairhaven district,[13] but elsewhere the intrusive rocks are chiefly biotite granites. If the quartz-feldspar veins are accepted as evidence of an underlying granitic mass from which the gold may have been derived, it is interesting to note that the feldspars of these veins wherever determined were plagioclase feldspars, albite or oligoclase. Plagioclase feldspar is an accessory constituent of the biotite granites, but it seems reasonable to assume that the character of the magma from which the veins are derived would be reflected in the veins themselves. The feldspars of the veins noted by Spurr [14] were orthoclase. It is not improbable, therefore, that the rock which is supposed to have produced the gold mineralization is a diorite such as has supplied the gold elsewhere in Alaska.

SEQUENCE OF MINERALIZATION.

It does not seem possible to assign a definite age to any of the several periods of mineralization which have been noted. The relative ages are known only in part. The two features of the age relations which are most impressive are (*a*) the number of periods of mineralization during which the various metals have been deposited and (*b*) the probable geologic youth of most of the sulphide, part of which is either gold bearing or was accompanied by gold and which seems to account best for certain of the well-known concentrations of gold.

[12] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 205, 1901.

[13] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, p. 30, 1905.

[14] Spurr, J. E., op. cit.

The order of succession may have been somewhat as follows:

1. The older quartz veins. These antedated the extreme metamorphism of the metamorphic series. How much of the disseminated sulphide and gold mineralization is assignable to this period is not clear. A large part of it is later.

2. Replacement deposits at limestone-schist contacts and along zones of bedding shear in limestone. The contact type includes the argentiferous galena of Iron Creek (p. 210); the shear-zone type includes the copper of Iron Creek and Copper Mountain (pp. 208, 217). The relative ages of these types are not determined. Galena occurs in small amounts as veinlets in the siliceous copper ores of Dickens Creek (p. 219) and as veinlets cutting the later quartz veins of Mountain Creek. If the galena mineralization is all of one age, the galena replacement deposits may be considerably younger than the copper replacement deposits.

3. The later quartz veins. The relative age of the copper replacement deposits and of the later quartz veins is also uncertain. That the former are merely a variation of the latter is questionable, however, as the copper sulphides are not prominent constituents of the quartz veins and the accessory feldspar and calcite of the veins are not known in the copper ores. In the Casadepaga district Smith found silicified limestone cut by later quartz veins. That the veins are of more than one period of intrusion is very probable, or at least their introduction was continued throughout some time, as shown by the vein structure at the Big Hurrah mine. From the evidence at hand, it might be best to consider the copper replacement deposits as older than the later quartz veins, although they may in part be contemporaneous. Geologically both of these types are fairly young. They are but slightly disturbed and certainly are subsequent to any of the periods of major deformation of the rocks of the peninsula. It is probable that they are younger than the late Cretaceous coal-bearing rocks, which occur in the eastern part of the peninsula, as those rocks are considerably faulted and folded.

4. Sulphide mineralization. Most of the sulphide minerals are probably younger than the later quartz veins. Practically all the stibnite and arsenopyrite and much pyrite are certainly younger. The pyrite is so abundant that it may have accompanied the mineralization of all periods. The age of the arsenopyrite and stibnite is shown by their association with the later veins. Movement sufficient to reopen the vein fissures and slightly shatter the veins supplied part of the openings into which these sulphides were injected. The movement that has occurred since the deposition of the stibnite is probably very slight, as those delicate ore bodies are not seriously disturbed. Slight movements are recorded in the several beach levels at Nome, the oldest of which may be Pliocene. The sulphide

mineralization would seem to be safely assignable to the Tertiary, but there is no evidence to indicate whether it was early or late in Tertiary time.

If the above interpretation is correct, it would seem that the sulphide mineralization and most of the gold mineralization of this area occurred subsequently to the mineralization which was effected by the granites in the York district. The York deposits are thought to be of Mesozoic age,[15] but that determination is also in doubt, as the granites do not occur in association with sedimentary rocks younger than Mississippian.

AREAS OF MINERALIZATION.

Most of the lode prospects of Seward Peninsula occur within two comparatively small areas—the York district, in the extreme northwestern part of the peninsula, and an area lying south of the Kigluaik and Bendeleben mountains, between Cripple River on the west and Council on the east. Prospects are also known near Kougarok Mountain, in the Kougarok Valley, on Kugruk River, at Omalik, and elsewhere, but most of the prospecting has been done within the two areas specified. It is very probable that these areas have been considered more favorable not so much because of the absence of lodes elsewhere which are as attractive as many or most of those that occur within the areas cited, but rather because of their proximity to tin placers in the York district and to the very productive gold placers of Nome, Solomon, and Council in the southern district. However, since the finding of gold at Nome, placer miners have pretty thoroughly covered the creeks of the entire peninsula and incidentally have investigated the promising lodes, so that, although the restriction of gold lodes may not be so great as is indicated by the distribution of the lode prospects, and other areas may possibly contain lodes of value, there was probably a relatively richer mineralization in the York and southern districts.

MINERAL DEPOSITS OTHER THAN GOLD.

In the foregoing description the bedrock occurrence of gold has been principally emphasized. There are, however, many other minerals on the peninsula of either proved or possible value. Some occurrences of these minerals are described in the following pages; others lie outside of the area under discussion.

Copper.—The copper ore of the area visited occurs in replacement deposits along sheared zones in limestones and schist and is characterized by features not observed in any of the other ores. At numerous localities the limestone, which is normally blue, is bleached

[15] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. — (in preparation).

to a lighter color or to white, and in places the bleaching is accompanied by silicification. These altered zones occur both at schist contacts and along planes of adjustment within the limestone and apparently unrelated to schist. The agency that effected the bleaching is not known. Silica has been introduced along the shear zones in places, and not uncommonly the bleached limestone is completely replaced. The copper sulphides that occur in these zones are contemporaneous with the quartz, but the quartz does not everywhere contain copper minerals.

This alteration of the limestone has been noted on Penny River, in the Solomon district, at Mount Dixon,[16] on Iron Creek, at Copper Mountain, on Slate Creek, on Manila Creek, and at Mount Distin. Copper minerals are associated with the altered limestone on Mount Dixon, Iron Creek, Manila Creek, and Copper Mountain, and zinc and lead at Mount Distin.

The quartz bodies in which the copper minerals occur seem to conform with the bedding of the limestone. The quartz contains many shrinkage cavities and retains the original bedding planes of the replaced rock. The most noticeable feature of the rock is its banded structure. Chalcopyrite, bornite, and pyrite are the usual sulphides observed. Galena is locally present. As all the developments are confined to the surface workings, malachite and azurite are the most abundant ore minerals.

Copper has been reported from the following localities:

Lost River, below the mouth of Tin Creek.[17]

Associated with the tin deposits of Ears Mountain.[17a]

About 3½ miles northwest of Kougarok Mountain, between Bismark, and Star creeks, tributaries of Quartz Creek.[18]

Three or four miles southeast of Kougarok Mountain.[18]

On Kougarok River near the mouth of Taylor Creek.[19]

Timber Creek and Tubutulic divide, Council City precinct.[20]

On the east coast of Darby Peninsula, about 3 miles north of Carson Creek.[20]

In the Bendeleben Mountains, on the divide between Kingsland and Nugget creeks.[20]

North side of Split Creek, a tributary of Bear Creek in the Fairhaven precinct.[21]

East of Iron Creek near the head of Sherette Creek, in the Kougarok precinct.

On Copper Mountain, Dickens Creek, and Copper Creek, at the head of Nome River.

On Dexter Creek, in the Nome district.[22]

On Mount Dixon, on Spruce Creek, and in the Moonlight Creek divide, in the Solomon district.[22]

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[16] Smith, P. S., op. cit. (Bull. 433), p. 115.

[17] Knopf, Adolph, Geology of the tin deposits of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 358, pp. 57–58, 1908.

[17a] Idem, p. 26.

[18] Mertie, J. B., jr., Lode and placer mining on Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 662, p. 440, 1917.

[19] Smith, P. S., Mineral deposits of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 345, p. 244, 1908.

[20] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 134–135, 1911.

[21] Harrington, G. L., Gold and platinum placers of Kiwalik-Koyuk region, Alaska: U. S. Geol. Survey Bull. 692, p. 399, 1917.

[22] Smith, P. S., op. cit. (Bull. 345), p. 243.

At the head of Twin Mountain Creek, in the Nome district.
At the head of Waterfall Creek.[23]
On the Klokerblok divide near the head of Eldorado Creek, in the Bluff region.
On the ridge at the head of Manila Creek.
Half a mile north of the mouth of Little Hurrah Creek, in the Solomon district.
Near the head of North Fork, a tributary of Last Chance Creek, in the Nome district.

At most of these localities copper is present in very small quantities, and at many of them development would hardly be justified. Little development work has been done at any locality.

Tungsten.—A small amount of tungsten has been recovered from the placers incidentally to the mining of gold. In the York district wolframite is associated with cassiterite in the tin deposits. It is present in very small quantities, so far as known, and has not contributed to the production. Scheelite is the mineral found in the placers and is present in small quantities at many localities. The concentrates from most of the streams of the Snake River valley contain scheelite. It occurs in the placers at Bluff, in the Council region, in the Solomon district, and in the Fairhaven district.

Sophie Gulch, a tributary of Rock Creek (p. 245), has been sluiced for its scheelite content. The gulch is cut in a shear zone in schist which contains a multitude of small quartz veins. The schist adjacent to the veins is impregnated with sulphides. Scheelite occurs with the sulphides that impregnate the schist and in the quartz veins that cut the schist. As the sulphide mineralization was later than the formation of the veins, and as scheelite appears to be contemporaneous with both the quartz and the sulphides, more than one period of tungsten mineralization seems certain.

Scheelite has also been mined from a quartz vein on Twin Mountain Creek and has been reported from lodes on the north side of Glacier Creek[24] and on the divide between Glacier and Anvil creeks.

Lead.—Within the area examined galena and sphalerite occur on Kruzgamepa River at the mouth of Iron Creek (p. 210) and on Steep Creek at the foot of Mount Distin (p. 232). At the former locality the ore is chiefly galena. It occurs as lenticular bodies along limestone-schist contacts. At Mount Distin the ore occurs in veinlets in a zone of bleached limestone. Galena is also present in very small quantities with the copper ores of Dickens Creek, Mountain Creek, Rock Creek, and Sophie Gulch.

Lead, in several places associated with zinc or with copper, has been reported from the following localities:

At Brooks Mountain.[25]
North of Rapid River, a tributary of Lost River.[25]
On Tin Creek, a tributary of Lost River.[25]
On Kruzgamepa River, at the mouth of Iron Creek (lead and zinc).

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[23] Mertie, J. B., jr., op. cit. (Bull. 662), p. 442.
[24] Idem, p. 437.
[25] Knopf, Adolph, op. cit. (Bull. 358), p. 42.

Northeast of Mount Bendeleben (lead and copper).
At Omalik.[26]
At the head of Steep Creek, on Mount Distin (lead and zinc).
On Kugruk River, at the forks of Independence Creek.
On Fish River, 5 or 6 miles above the mouth of the Niukluk.[27]
On Waterfall Creek.[27]

Most of the galena discovered on the peninsula has been reported to be silver-bearing. The property on Kugruk River has been actively exploited for several years and is the best-developed silver-lead prospect on the peninsula. A considerable tonnage of high-grade ore is reported to have been mined, but no shipments have been made. This property has not been visited by a member of the Survey.

Zinc.—The presence of sphalerite with galena at Mount Distin and on Kruzgamepa River has been referred to in connection with the occurrence of lead. Mertie[28] reports zinc to be present on the ridge between Penny River and the head of Oregon Creek. The ore consists of sphalerite and a little pyrite in a gangue of quartz.

Iron.—Five groups of iron claims have been staked on Cripple River. The ore is mostly limonite (pp. 258–261). Too little development work has been done to determine the nature of the occurrence. Mertie[29] reports sulphides as present with the ore at the Mogul group of claims and suggests that the iron may be merely gossan material capping a sulphide vein. The Cub Bear group of claims was visited by the writer. No sulphides were observed at this locality. The iron ore occurs in a zone perhaps 50 or 100 feet wide and extending for several thousand feet along the crest of an anticlinal fold in limestone. A small quantity of the ore is botryoidal limonite, with which some oxide of manganese occurs. Most of the material is iron-stained limestone and represents no great concentration of the iron oxide. The observed structural relations strongly suggest that the ore has been deposited from aqueous solutions circulating along the fissured crest of the fold.

Platinum.—Platinum is recovered from the placers of Dime Creek incidentally to the mining of placer gold. The ratio of the platinum to the gold content of the gravels is thought to be about 1 ounce of platinum to $4,000 in gold. Attempts have been made to locate the bedrock source of the platinum, and prospectors have received favorable returns on some of the material which they have had assayed. Specimens of greenstone dike rock which were reported to contain a trace of platinum were submitted to the Geological Survey, but assays made on this material for the Survey by competent chemists

[26] Mendenhall, W. C., A reconnaissance of the Norton Bay region, Alaska: U. S. Geol. Survey Special Pub., pp. 213-214, 1901.
[27] Mertie, J. B., jr., op. cit. (Bull. 662), p. 446.
[28] Idem, p. 447.
[29] Idem, p. 444.

have shown the rock to contain no platinum. Sulphides reported to contain platinum have been referred to under "Bismuth." The fact that platinum has seldom been found in hard rock does not preclude the possibility of finding it, but it can not be too strongly emphasized that platinum is an exceedingly difficult element to determine analytically. A platinum content is frequently reported when the element is not present. Prospectors can not afford to accept determinations by any chemist except one who is especially qualified to handle that particular work.

Antimony.—The stibnite that occurs in the area examined is commonly associated with the later quartz veins. Kidneys of stibnite accompanied by very little quartz have been found along shear zones in schist at several localities, but the ore bodies have been small. The best-known localities are the Sliscovich mine, on Manila Creek and the Hed & Strand mine, on Lost Creek (pp. 226, 229).

In all the deposits observed the stibnite seems to have been introduced since the formation of the veins. Apparently after the intrusion of the quartz movement continued to take place along the vein fissures, and they were reopened and the veins shattered. At some localities the stibnite occurs as irregular bodies between the vein and its schist wall and as nests and stringers in the vein itself. In most localities it is present only as veinlets in the quartz.

The stibnite is usually accompanied by some pyrite and a variable amount of contemporaneous quartz. In the richest specimens the stibnite occurs as distinct acicular crystals, some of which are an inch or more long, and the quartz is present as well-formed but smaller crystals with good terminations. In the lower-grade ore the stibnite is finely crystalline, and quartz forms most of the rock. Gold is present with the stibnite at the Sliscovich mine and at several places on Anvil Creek.

The localities at which stibnite has been reported to occur are as follows:

Sliscovich mine, Manila Creek.
Hed & Strand mine, Lost Creek.
Cold Creek.
Divide between Manila and Hobson creeks.
Big Hurrah Creek
Head of Waterfall Creek.[30]
Boulder lode.[31]
Quartz Gulch, tributary to Anvil Creek.
Winsted tunnel, northwest bank of Anvil Creek above Specimen Gulch.
Olsen shaft, southeast bank of Anvil Creek below Specimen Gulch.
Northwest bank of Anvil Creek below Quartz Gulch.
Ridge between Anvil and Glacier creeks, southwest of Snow Gulch.

[30] Mertie, J. B., jr., op. cit., p. 438.
[31] Idem, p. 440.

Lost River region.[32]
Head of Bonita Creek, a tributary of Osborn Creek.[33]
California quartz lode, on Goldbottom Creek.[33]
Quartz veins of the Solomon-Casadepaga region.[33]
West side of Brooks Mountain.[33]
Omalik mine.[33]

Tin.—Lode tin is known only in the York district. Deposits have been prospected at Ears Mountain, Lost River, Potato Mountain, and Cape Mountain. Cassiterite occurs in quartz veins, porphyry dikes, and contact-metamorphic deposits closely related to granite bosses. Development work has been in progress at the Lost River locality for the last three seasons, but no work has been done at the other localities in recent years. The production from the lodes has been negligible. Most of the tin mined has come from the placers of Buck and Grouse creeks. The placers of Cape Mountain have produced some tin and, together with those on the streams flowing north from Potato Mountain, promise production for the future. Tin has been recognized in the placers of Humboldt Creek, in the Fairhaven district, and Goldbottom Creek, in the Nome district.

Bismuth.—Bismuth has been found at only one locality on the peninsula, on Charley Creek, a tributary of Stewart River (p. 223), where a quartz vein contains some bismuthinite (bismuth sulphide). The sulphide content of the vein appears to be low, but as almost no work has been done on the property very little of the vein is exposed. This occurrence has been of especial interest because the sulphide was reported to carry 2 ounces of platinum to the ton. An assay made on some of the material for the Geological Survey did not show any trace of platinum.

Graphite.—Graphite-bearing schists occur in both the Nome group and the Kigluaik group. The graphite in the schist of the Nome group is in a very finely divided state and is of no economic interest. A belt of schist of the Kigluaik group in which the graphite occurs as flakes and in which concentrations of rather pure material occur locally extends from the head of Grand Central River northeastward to the vicinity of Graphite Bay, an arm of Imuruk Basin. Several shipments of selected material have been made from the Graphite Bay locality (p. 222).

Mercury.—Cinnabar is a constituent of the placer concentrates in the vicinity of Bluff, at Koyana Creek, and at Budd Creek, in the Port Clarence precinct, and has been reported from other localities. The source of the material at Bluff is said to have been discovered in one of the schist lodes of that locality, but no details of the occurrence are known.

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[32] Knopf, Adolph, op. cit., p. 59.
[33] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 57–59, 1916.

Coal.—A little coal occurs in the Cretaceous sediments of the eastern part of the peninsula. It is lignite of fair quality and is generally considered to have about one-half the fuel value of average Pacific coast coal. It is being mined at present on Kugruk River and has been mined at Chicago Creek, both in the Candle district. Thus far, because of the low grade of the product, the high cost of transportation has limited its use to the vicinity of the mines. No great tonnage is known to be available. Coal has been found at the following localities:

Chicago Creek, tributary to Kugruk River.[34]
Kugruk River near Montana Creek.[34]
Koyuk River near mouth.[35]
Wilson Creek, a headwater tributary of Kiwalik River.[36]
Hunter Creek near the mouth of the Buckland.[35]

THE LODE DEPOSITS.

BLUFF REGION.

The Bluff region, which has produced about $1,500,000 worth of placer gold, includes a small area lying on the shores of Bering Sea about 50 miles east of Nome. Its salient geologic features are simple, though the details are complex, due to folding and faulting. Limestone is the dominating country rock and occurs in a roughly triangular area, whose base is on the coast and whose apex is inland. This limestone appears to be bounded on the inland side (fig. 6) by schist which here and there contains some thin limestone beds. Some bands of schist also occur within the limestone, and these are important to the miner because they are the loci of the strongest mineralization. These bands of schist may in part be altered igneous intrusives, but this is uncertain. The small valleys of the region have a gravel filling, which is nearly everywhere auriferous and which contains some workable gold placers. The gold placers of Daniels Creek and of the adjacent beach line have furnished much the larger part of the gold output of the region.

Placer gold was discovered at the mouth of Daniels Creek in 1889.[37] The beach gravels at this locality were also gold bearing and for a distance of 1,000 feet are said to have been "probably the richest deposit of this kind ever found in the world."[38] It is estimated that the pay streak must have averaged $150 to the cubic yard.[39] Gold

[34] Henshaw, F. F., Mining in the Fairhaven precinct: U. S. Geol. Survey Bull. 379, pp. 362–363, 1909; Mining in Seward Peninsula: U. S. Geol. Survey Bull. 442, pp. 368–369, 1910.

[35] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, p. 139, 1911.

[36] Harrington, G. L., Gold and platinum placers of Kiwalik-Koyuk regions, Alaska: U. S. Geol. Survey Bull. 692, p. 384, 1919.

[37] Brooks, A. H., Richardson, G. B., and Collier, A. J., Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 104, 1901.

[38] Brooks, A. H., U. S. Geol. Survey Bull. 328, p. 288, 1908.

[39] Idem, p. 289.

has also been mined from the creeks both east and west of Daniels Creek, but lower Daniels Creek and the beach at its mouth have proved to be the attractive placers of the area.

Brooks [40] pointed out from his study of the placers in 1906 that "(1) the source of the gold is entirely local; (2) where richest * * * there appears to have been little sorting action by water; (3) the gold is so intimately associated with mica schist débris that most probably the schist had a close connection with its origin." He also described certain zones of mineralized schist exposed in the bluffs east of the mouth of Daniels Creek.

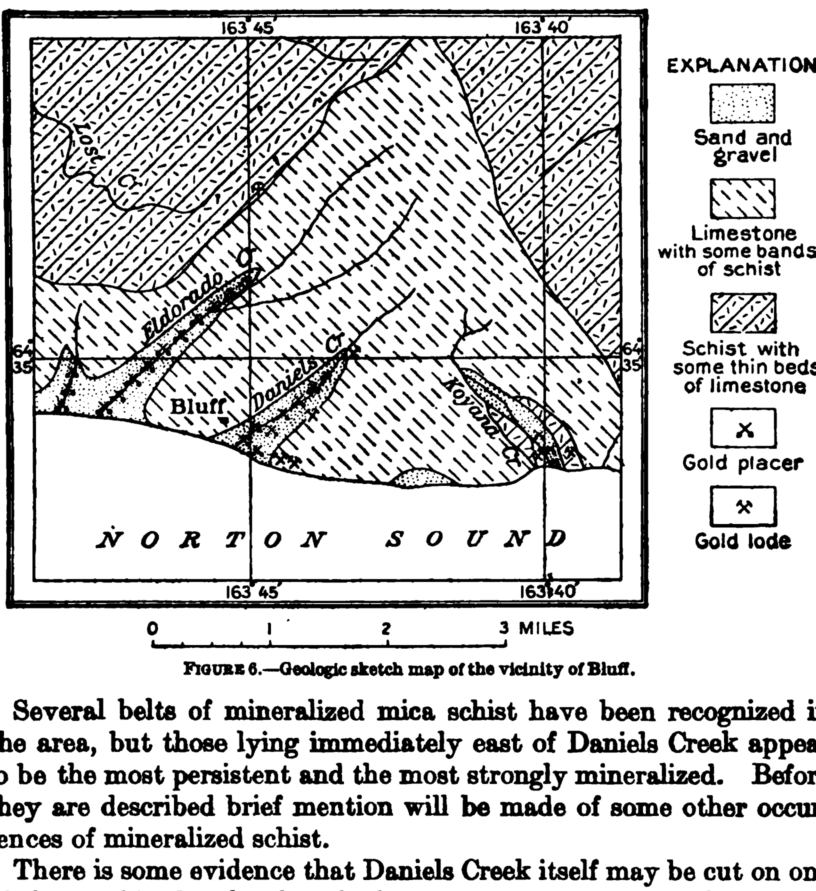

FIGURE 6.—Geologic sketch map of the vicinity of Bluff.

Several belts of mineralized mica schist have been recognized in the area, but those lying immediately east of Daniels Creek appear to be the most persistent and the most strongly mineralized. Before they are described brief mention will be made of some other occurrences of mineralized schist.

There is some evidence that Daniels Creek itself may be cut on one of these schist bands, though the nearest exposed bedrock on both sides is limestone. There is a schist band in the limestone at the mouth of Koyana Creek, and here mineralized zones have been opened up in a small way.

About 100 yards west of Koyana Creek near sea level an adit has been driven for 30 feet along a quartz vein in a sheared zone in the

[40] Brooks, A. H., U. S. Geol. Survey Bull. 328, p. 289, 1908.

schist. Owing to the timbering the relations and behavior of the vein can not be made out, but at the face an 8-inch stringer of quartz of the later-vein type (p. 173) is exposed. About a foot of red iron-stained gougelike material occurs on the vein wall. Sulphides occur in the quartz of the vein and in the schists near the vein but are largely localized along the contact of quartz and schist. Pyrite and arsenopyrite are abundant in the several places exposed, arsenopyrite the more plentifully. The zone of decomposition that forms so prominent a part of the lode is probably the result of the decomposition of the sulphides, especially of those contained in the schist. The tunnel was driven by David Lylles, but only assessment work has been done on the claim during the last six years. No information was obtained concerning the gold found.

About 50 yards east of Koyana Creek along the beach an adit reported to be 40 to 60 feet long is driven in a direction N. 50° E. A shaft sunk from the top of the escarpment to connect with the adit is said to be 75 feet deep. At the time of visit the shaft was filled with ice and water and a snowdrift covered the adit entrance, so that neither could be entered. This is known as the Hill property and is now claimed by Brady Hanson. Some ore was taken out, but very little has been shipped. The property was last worked in 1910. Material on the dump of the shaft is quartz-mica schist and quartz-vein material, apparently of the later-vein type.

A little work has been done on a metallized quartz vein on the Bunker Hill lode, on the divide between Eldorado Creek and Klokerblok River near the top of the ridge that parallels Eldorado Creek on the west (fig. 6). It appears to lie at or close to the contact between the limestones and schists.

The vein where exposed is about 5½ feet wide. Its relations to the country rock and its strike are poorly exposed by two shallow trenches about 2 feet deep and 20 feet long, of which one crosscuts the vein and the other follows its strike. The vein strikes about N. 5° E. and appears to dip west at an angle near the vertical. The footwall is limestone; the hanging wall schist. Where best exposed the vein shows a central portion of about 18 inches of unmineralized quartz with a foot of mineralized quartz on the footwall and 2½ feet on the hanging wall.

The vein is stained with carbonates, both azurite and malachite, and is said to carry gold. An assay of $80 in gold to the ton is reported by the owner, but nothing is known of the nature of the sample. The copper content is said to be small. A specimen of the metallized portion of the vein shows chalcopyrite and pyrite in small amounts.

As stated above, the deposits adjacent to and just east of Daniels Creek are the most valuable of the region. Here the mineralized

schist bands in the limestone were staked as lode claims soon after the Daniels Creek placers were discovered. The original locators have carried on development work on these claims in a small way for some 20 years. Three lodes are recognized from Daniels Creek eastward, the Sea Gull, Idaho, and Eskimo lodes (fig. 7). They trend in a general northerly direction and except where they crop out on the cliff face are concealed by the tundra vegetation and exposed only by the mining operations. The Sea Gull and Idaho lodes lie parallel to each other; the Eskimo lode has the same attitude to a point 2,000 feet from the beach, where it swings slightly to the west, and at 4,000 feet from the beach the interval between the Eskimo and Idaho lodes is reduced by about one-half. Prospecting has shown the lodes to be continuous but of varying width, the width increasing to the north and in depth. Where explored at the croppings on the sea cliff maximum widths of 60, 165, and 150 feet are reported for the Sea Gull, Idaho, and Eskimo lodes, respectively. At 4,000 feet from the beach the widths are estimated from the workings to be 100, 200, and 200 feet, respectively.

The lodes are made up essentially of quartz-mica schist, silvery gray where fresh and buff where weathered. Quartz veins seem to occur everywhere throughout the schist and range in size from stringers less than 1 inch to well-defined veins several feet in width. Exposures are not adequate to afford conclusive evidence concerning the disposition of the quartz, but the veins appear to be somewhat concentrated along the margins of the lodes. The sulphides arsenopyrite and pyrite are recognizable in some of the lode material.

Four claims are staked along the strike of each of the three lodes, extending from the sea cliff nearly to the head of Daniels Creek valley. The most southerly claim on the Eskimo lode is held by John Corrigan; the remaining eleven claims by Charles Megan, Henry Megan, and W. J. Somerville. The schist zones have been traced by pits and shafts and are said to contain gold wherever prospected. Most of the work has been done about three-quarters of a mile from the beach, where fourteen shafts, ranging in depth from 30 to 100 feet and aggregating 657 feet were pointed out to the writer. They were distributed as follows: Sea Gull, five shafts, 240 feet; Idaho, six shafts, 335 feet; Eskimo, three shafts, 82 feet. Numerous pits and trenches have also been dug along the strike of the lodes, and on the Idaho lode at the beach 145 feet of tunnel, winze, and crosscut work has been done. The approximate location and depth of the workings are shown in figure 7. Mining has not been carried to any great depth, for several reasons. The shafts have been sunk chiefly for prospecting purposes, and it is said that no shaft failed to find gold-bearing quartz in sufficient quantities and rich enough to mine. The present mill equipment will handle, efficiently, only the oxidized surface portion of the

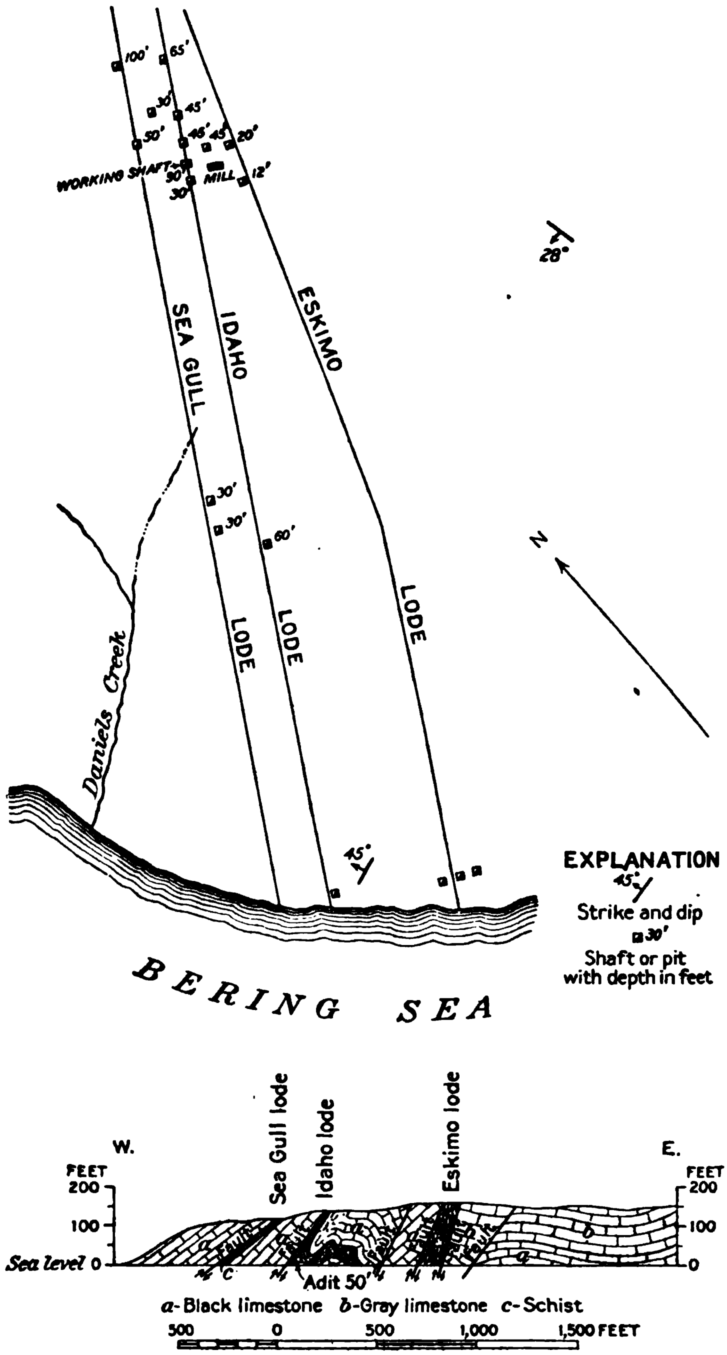

FIGURE 7.—Sketch map and geologic section showing gold lodes near Bluff.

lodes. There is no timber in the vicinity of Bluff, and mine supports are difficult to obtain. As the lode material is soft no considerable depth can be reached without danger from caving. Only the present working shaft is timbered; all the others are caved and inaccessible.

The rock formations with which the lode deposits are associated are exposed on the bluff that faces the sea just east of Daniels Creek (fig. 7). Three formations are recognized, a dark-blue carbonaceous limestone, a gray limestone interbedded with mica and chlorite schist, and the quartz-mica schist which forms the gold-bearing lodes. The lithology of the limestones is not uniform but shows variations which are dependent largely upon structural relations. The limestones are everywhere marmarized and show massive, slightly schistose, and highly schistose phases. The schist consists predominantly of quartz with some micaceous mineral. Muscovite is the common accessory constituent, with which usually occurs some chlorite, and locally the chlorite is in excess of the muscovite. The exposed schist is buff, and the less altered schist a silvery gray. The structural relations of the formations as exposed on the sea cliff are shown in figure 7.

East of the Eskimo lode the carbonaceous limestone is exposed at the base of the cliff. About 50 feet of the blue limestone is overlain by 100 feet or more of gray limestone. The contact is a fault plane concordant with the bedding of the limestones, which appear to be conformable. The rocks are gently folded into a syncline that pitches north. The blue limestone at the contact is dense, dark blue, and platy. The rock contains abundant graphite and considerable muscovite. Quartz is present in scattered grains that show the effects of strain. Cordierite is also present in small amounts. The overlying gray limestone is altered for a distance of several feetfrom the contact to a coarsely crystalline marble. The limestone lamination planes are marked by iron stain, which gives to the cross-fracture surfaces a blotched appearance.

The syncline is terminated on the west by a fault that brings the gray limestone down to form the footwall of the Eskimo lode. As indicated in the sketch map, this is the only occurrence of the gray limestone with the mineralized schists. The carbonaceous limestone adjacent to the schist lodes usually shows a schistose structure. This structure may be so well developed as to obscure its relation to the limestone, but where traced away from the lode the schistosity decreases until marmarized and slightly schistose but easily recognizable limestone occurs. The locus of deformation seems to be the Idaho lode, as here the folding and minor faulting and alteration of the limestone is most intense.

Only the major structural features are represented in figure 7. Many of the features are obscured by slide and made uncertain by the

inaccessibility of the cliff face. Minor faulting and folding, or rather shattering and crumpling, is very common, especially in the vicinity of the lodes. Small faults occur in the blue limestone that do not extend into the gray, and vice versa. Many of these faults have a low angle of dip and swing off along the bedding planes. West of the Sea Gull lode the carbonaceous limestone is best exposed and least disturbed. It is fine textured and crystalline and occurs in beds half an inch to 8 inches in thickness, which strike N. 21° W. and dip 30° W. It is much jointed but broken in clean-cut blocks. The joints are filled with calcite veinlets, which average less than an inch in width and are spaced but a few inches apart. About 350 feet of the formation is exposed, the base in fault contact and the top eroded.

Some idea of the relations of the lodes to the country rock can be obtained at the exposure on the sea cliff. The underground exposures show little, as the development work in the one accessible shaft is confined to a single quartz vein and does not crosscut the schist body or show the relations of the schist to the wall rock.

The Eskimo lode, the most easterly of the three schist zones, is about 150 feet wide. It dips about 70° W. and occurs in fault contact with both footwall and hanging wall. The hanging wall is carbonaceous limestone; the footwall gray limestone. The sulphide mineralization of the schist was apparently concentrated along the footwall, where the limestone is stained buff and the schist weathers to a fine friable material and is highly iron stained. Microscopic examination of the rocks at the contact shows the schist to be probably 98 per cent quartz. It is strained, and the crystals are elongate parallel to the schistosity. A little muscovite is the only other original constituent present in any notable quantity, although accessory zircon occurs through the quartz. Calcite occurs in veinlets through the rock. The limestone is finely crystalline, is stained by limonite, and contains scattered cubes of pyrite.

Quartz veinlets are abundant in the schist, especially near the margin of the lode. No large or well-defined veins crop out. Fresh sulphides were not observed.

The Idaho lode is exposed on the cliff top about 650 feet west of the Eskimo lode. It differs from the other lodes chiefly in its structural relations with the limestone. The hanging wall is carbonaceous limestone, which dips 45° W. A fault dipping 35° W. forms the contact, along which 1 foot or more of gouge and talclike material occurs. The footwall is carbonaceous limestone, which near the base of the cliff occurs in folded relations with the schist of the lode. The infolding of the two formations is distinct, being outlined in minor as well as major folds. These relations are shown in figure 8.

The schist of the lode is highly folded and crenulated within itself. Quartz stringers occur through the schist in great numbers and

appear to have been deformed with the schist, as they are badly shattered. The individual veins are mostly of small size and in general concordant with the schistosity of the lode rock. Along the hanging wall the veins are most abundant and reach several inches in width. The fault contact (fig. 8), which shows gouge and highly iron-stained schist, appears to be the best-mineralized part of the lode. The concentration of mineralization along the walls in this and the other lodes may in places be more apparent than real, being due largely to the fact that the contact surface afforded a better opportunity for water circulation and hence more complete decomposition of the sulphides contained in the schist. The gold content can be determined only by systematic assays. Assays of the Idaho lode are said to show gold throughout the width of the schist zone. The tenor is very irregular, however, ranging from $2 to $180 a ton.

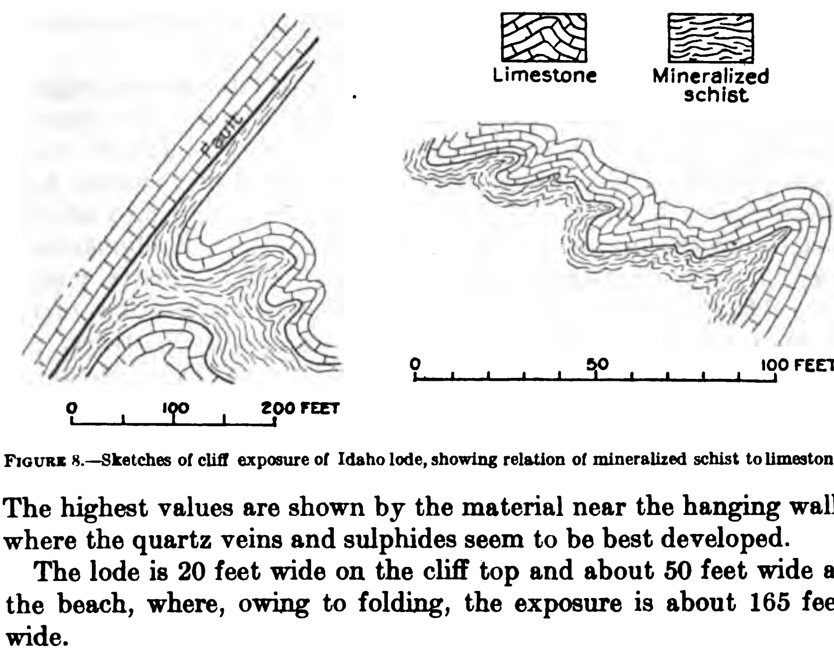

FIGURE 8.—Sketches of cliff exposure of Idaho lode, showing relation of mineralized schist to limestone

The highest values are shown by the material near the hanging wall, where the quartz veins and sulphides seem to be best developed.

The lode is 20 feet wide on the cliff top and about 50 feet wide at the beach, where, owing to folding, the exposure is about 165 feet wide.

The wall rock of the Idaho lode is a carbonaceous limestone consisting of about 90 per cent calcite, 5 per cent graphite, 4 per cent angular quartz, and 1 per cent sericite. Close to the lode it is distinctly schistose and marmarized and contains some pyrite. Metamorphism is more noticeable here than in the vicinity of either of the other lodes. Quartz is the dominating mineral of the lode schist, and with it occur chlorite and muscovite, chlorite the more abundantly. Accessory apatite and zircon occur through the quartz. Calcite and limonite are abundant secondary constituents. Polished surfaces of the vein quartz material show very minute particles of

free gold. The sulphide content is not determinable at the cliff exposure, owing to the extreme alteration of the more highly mineralized portion of the exposed lode.

The Sea Gull lode crops out along the top of the sea cliff about 250 feet west of the Idaho lode. Exposures on the cliff face are obscured by talus. The lode is 10 feet wide at the surface and is said to be 60 feet wide at the beach, which is 110 feet lower in elevation. The increase in width is said not to be due to folding, like that in the Idaho lode. Both hanging wall and footwall are carbonaceous limestone, which dips about 30° and 45° W., respectively. The lode dips about 30° W. The hanging-wall contact is a fault surface, along which movement is recorded by gouge. The footwall contact is not exposed, but the relations are probably those of faulting. Along the hanging wall is exposed a zone of highly iron-stained schist, which is impregnated with quartz stringers from 1 to 3 inches wide. It is said that development work along this zone has exposed 6 to 8 feet of solid quartz at several places.

The limestone in which the lode occurs is crystalline and slightly schistose. The little-altered schist of the lode is a gray silvery rock, containing considerable sulphide both in the quartz and in the micaceous portion of the schist. On decomposition it becomes buff. Microscopic examination of a specimen from the hanging-wall contact shows the presence of abundant kyanite and of sillimanite in very fine crystals, together with the usual strained quartz, muscovite, chlorite, and decomposed sulphides. A polished surface of the quartz veinlet material shows free gold in very minute particles.

Work was being done at the time of visit on the Idaho lode about 4,000 feet from the beach. This was the only working accessible. A 90-foot shaft has been sunk on a quartz vein, and about 220 feet of drifts have been run along its strike. The vein is almost vertical. Where opened at the surface it was 8 inches wide, but on the 80-foot level it has a width of 7 feet. As exposed the vein shows three distinct types—an iron-stained shattered quartz, a green phase, and a softer hematitic phase. Where the three types are present, the quartz almost always forms the central part of the vein. The other types are less uniformly disposed. The hematitic material tends to localize along the walls, but in places it is confined to one wall. The green rock occurs between the hematite and the quartz or, if the hematite is absent, next to the wall. In several places it was observed extending into the quartz, and in one place it is surrounded by quartz.

The quartz of the vein is white and opaque and shows columnar crystals oriented transverse to the vein. Openings showing well-terminated crystals are common. The veins are of the later-vein type (p. 173). They are badly shattered, and in the fractures a green

chloritic material commonly occurs. The green rock of the vein is composed chiefly of the chloritic material, in which occurs considerable of the vein quartz and fresh sulphides, chiefly arsenopyrite and some pyrite. In thin section the chloritic substance is pale yellow, is highly birefringent, and occurs as minute flakes in aggregate structure. In hand specimen the rock is deep green to yellowish green, hard, and usually cellular. The hematitic material is badly decomposed quartz schist. It is soft and crumbles in the hand. The unaltered wall rock is a silvery gray quartz-mica schist in which quartz is the chief constituent. The vein quartz is prominent even in small specimens of the schist. Viewed as a whole the wall rock is schistose; in detail it is essentially quartz. Next to the veins it breaks down readily and is of buff color.

The vein is continuous so far as followed but is not constant in width and shows still greater variation in make-up. In some places the quartz rock predominates, in others the green rock, and near the surface the red oxidized material of the vein. The red rock is favored by the operators, because of its high gold content and also because it is free milling. The buff schist is said to carry some gold but is not considered good pay. A certain amount of it is mined with the vein material and is milled as a part of the run of mine ore, which is said to have a value of $5 to $6 a ton. All the veins encountered in the prospect shafts are said to have been of this general type, varying in width and in proportion of the materials. The green rock occurs on the Sea Gull and probably on the Eskimo lode. Near the surface some of the veins are composed almost entirely of red oxidized material.

Prospecting has been confined to the oxidized zone of the lodes. The sulphide material was nowhere seen exposed, and its relations could not be determined. In specimens the relations are further obscured by the great amount of chloritic material associated with the sulphides. This chloritic substance is an infiltration product and is clearly later than the sulphide and quartz. The freshest of the quartz is cut by microscopic veinlets of this material, areas of unaltered arsenopyrite are surrounded by it, and shattered crystals are seamed with it. From the nature of the decomposed vein material and from similar occurrences elsewhere on Seward Peninsula, the sulphides are judged to be later than the quartz veins, having impregnated the schist of the vein walls and filled fractures in the quartz. The decomposed hematitic material, which is undoubtedly schist that has been impregnated by sulphides and weathered, mills free gold, but some gold is not recovered on the plates, and the gold content is probably in part base. Gold also occurs in the quartz of the open-structured veins, so that more than one period of gold mineralization may be represented.

In local usage the terms "hard ore" and "soft ore" are applied to the quartz-vein material and the schist country rock, respectively. Both the hard and soft ore are reported to carry gold, but the hard ore is said to be of higher grade than the soft. This relation does not necessarily mean that the schist and the quartz were mineralized individually, for the quartz solutions have so squeezed through the schist mass that the smallest openings have been filled, and many of the veinlets are so minute and occur in such an attitude that they would impart little of their hardness or resistance to the schist mass as a whole. The quartz may still remain the gold carrier, and thus the gold content of the soft ore or schist may be due to its contained metallized quartz veinlets. The larger veins have probably been considerably enriched by the later sulphide mineralization.

Four men were employed in mining at the time of the writer's visit. Dumps are taken out during the winter, and the ore is milled in the summer. It is crushed to 1-inch size in a small jaw crusher and reduced to 30-mesh in a Cover rod mill. The pulp is passed over amalgamation plates for gold recovery and then over two Monarch tables. The tables effect a concentration of 5 to 1 for the hard quartz ore and 20 to 1 for the soft schist ore. The concentrates are stacked. The mill has a rated capacity of 40 tons in 24 hours; the average run of quartz ore is 6 to 8 tons through 30-mesh in 24 hours.

The lodes have not been crosscut in any of the underground operations. The importance of crosscutting lodes of this type is very evident. From the evidence at hand it seems reasonable to believe that these zones contain one or more roughly parallel quartz veins, and although a single vein of low or moderate gold content may not prove to be an attractive mining venture, the presence of a number of veins which would in themselves offer a sufficient tonnage or which occur sufficiently close to one another to make mining of the entire schist and quartz body practicable might make the lode a commercial ore body.

Concentrates from Daniels Creek show scheelite and cinnabar, but neither of these minerals was observed to occur in the mill concentrates. The source of the scheelite is not definitely known, although it is probably present as a minor constituent of the quartz veins. Veins of this type carry scheelite in the Nome region. The cinnabar is said to have been found in place in the Eskimo lode associated with the schist. The working in which this was discovered is now caved, and the occurrence was not seen by the writer. Cinnabar is also said to be present in small amounts in the Idaho and Sea Gull lodes, and mercury is sometimes liberated on heating the mill pulp. It is also known in the placers of Eldorado and Swede creeks but has not been traced to its source. The fact that little placer ground

has been discovered on Daniels Creek above the point where the lode system crosses its valley is further evidence that these lodes supplied the gold for the rich beach and creek placers.

SOLOMON DISTRICT.

Placer gold is widely distributed in the Solomon River basin, about 30 miles east of Nome, but little very rich placer ground has been found. Most of the successful alluvial mining has been done on the large bodies of auriferous gravel by means of dredges.

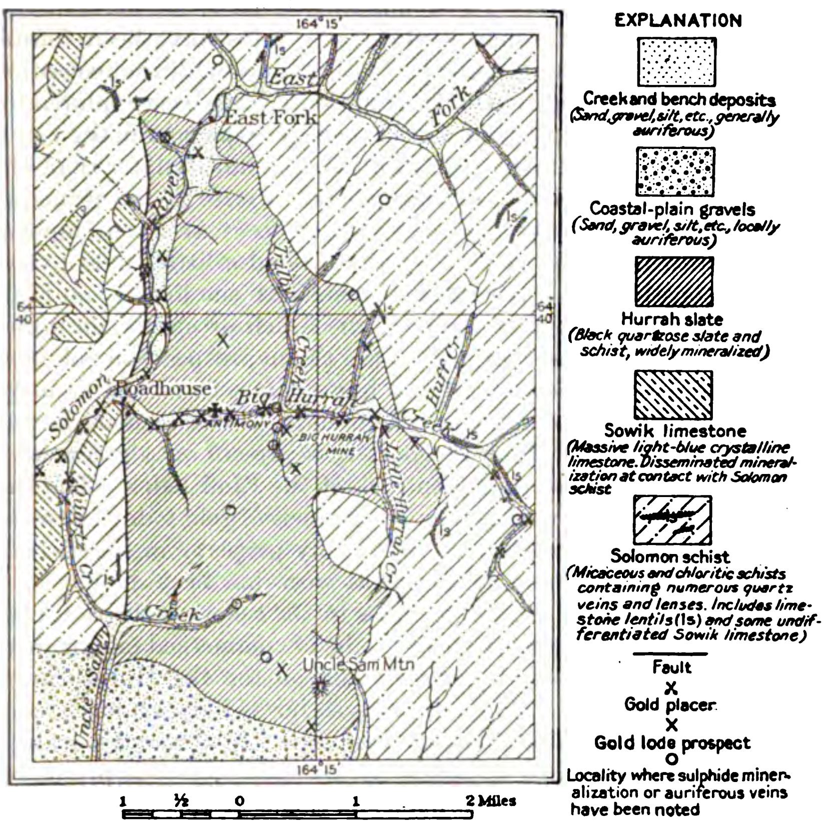

FIGURE 9.—Geologic map of part of Solomon district.

Smith [41] has mapped the region in detail, and part of his geologic map is here reproduced as figure 9. The Solomon schist, as determined by Smith, is the oldest formation. It consists essentially of micaceous and chloritic schists, with some lenses of limestone. This formation is succeeded by the Sowik limestone, 400 to 1,000 feet in thickness. Smith provisionally assigned the Sowik to the Ordovi-

[41] Smith, P. S., The geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, 1910.

cian(?), but Brooks now believes that it may be Carboniferous (p. 168). The Hurrah slate, a still higher formation, is made up of black and quartzose slates and schists.

Nearly all the most promising lode prospects of the region are in the Hurrah slate. There are, however, some quartz veins in the Solomon schist, and the contact between this schist and the overlying limestone is a common locus of disseminated mineralization. It is a significant fact that the gold of much of the richest placer ground of the district has been derived from the auriferous quartz veins of the Hurrah slate. The dominating trend of the lodes in this slate is northwest, but some northeasterly veins have been found. The veins are of the later-vein type (p. 173) and, with the exception of one antimony-bearing vein on Hurrah Creek, have been explored for their gold content. Sulphides are as a rule not conspicuous in the veins, and the gold is free-milling. The sulphides are mostly later than the veins and occur as veinlets in the quartz. Pyrite is the principal sulphide observed and the only one seen to occur as a contemporaneous constituent of the veins. Pyrrhotite and a little chalcopyrite are minor constituents of the sulphide veinlet at one locality on Hurrah Creek, and arsenopyrite occurs at the Alden prospects, on upper West Creek, in the schist area, and at the Flynn prospect, on Solomon River. On West Creek arsenopyrite impregnates the schist country rock in the same association in which it is so conspicuous in the Nome region. At the Flynn prospect it is present in a green chloritic rock very similar to the green rock of the Bluff lodes. The Big Hurrah quartz mine, which is the one productive gold lode of Seward Peninsula, is in this district. It is the only property in the district on which any considerable development work has been done.

As the occurrence of auriferous lodes in the Solomon district, cutting the Hurrah slate, may yet prove to be of commercial importance, some brief notes on several prospects and on the Big Hurrah mine will be presented, although the district, so far as lode mining is concerned, is now practically abandoned and the underground workings are for the most part inaccessible. A further difficulty is presented by the fact that not even the names of some of the prospects described could be learned. They have, however, all been marked on the map (fig. 9) by an appropriate symbol and can be identified by the descriptions of localities given in the text.

On the south side of Uncle Sam Mountain, near the level of the coastal plain, a shaft has been sunk on a quartz vein that cuts the Hurrah slate. The property has apparently not been worked for many years, and the relations of the vein could not be seen. The shaft is full of ice within 15 feet of the surface and is timbered to that depth. To judge from material on the dump the vein was probably 2 or 3 feet wide and from the drift has a strike of about N. 40° E.

The quartz is clearly of the later-vein type, showing comb structure and cavities lined with perfectly terminated crystals. No sulphides are seen in the quartz, and no fresh sulphides in the slate associated with the quartz contacts. Specks of limonite through the slate probably indicate decomposition of sulphides contained in it.

About 300 feet from the top on the south slope of Uncle Sam Mountain a massive iron-stained quartz ledge, 7 feet or more wide, has been exposed by an open cut. The vein strikes N. 45° W. and stands nearly vertical. The outcrop is iron stained, but no sulphides were observed. The transition from massive quartz to quartz with slate inclusions to slate with a little quartz is observed and probably indicates reopening of the vein. Decomposed feldspar is present in the vein quartz in small amounts. The wall rock is the Hurrah slate.

Iron-stained quartz that contains sulphides occurs as drift near the head of Buena Vista Creek, on the east slope of the valley, at an elevation of 500 feet. The ledge is not exposed. The country rock is the Hurrah slate. The quartz is of the later-vein type and shows many original cavities into which well-terminated quartz crystals project. Pyrite is abundant and apparently later than the vein. It fills cavities and coats quartz crystals.

Two openings have been made on quartz veins at the mouth of Buena Vista Creek, on the east bank. One is now caved and inaccessible; the other, a drift 15 feet long, follows an 8-inch quartz vein. The vein strikes N. 45° W. and dips 60° S. The wall rock, which is black slate, strikes N. 50° E. and dips 45° N. The vein is variable in attitude, here cutting the bedding of the slate, there following it. Just north of the drift face the vein is offset 5 feet by a fault that has followed the bedding of the slate. This is a minor dislocation such as is commonly observed to affect the later quartz veins. Ribbon rock was not seen here, the vein walls being clean cut and not affected by the mineralization. The quartz is iron stained on fracture planes and contains pyrite, which occurs both as crystals through the quartz and in cavities and fractures later than the quartz. Two ages of sulphide mineralization are here apparent.

Considerable prospecting has been done about half a mile from the mouth of an unnamed stream that enters Big Hurrah Creek from the north a quarter of a mile below Little Hurrah Creek. The workings are now so caved and slumped that no exposures of the veins can be seen. There are probably a dozen open cuts from 5 to 30 feet long and 3 or 4 feet deep and three shafts, now caved and filled with water. The country rock is the Hurrah slate.

Quartz on the dump at the main shaft is of open texture, coarsely crystalline, and clearly of the later-vein type. Considerable sulphide occurs through the quartz in well-defined veins, which in places swell to nests. Pyrite and pyrrhotite are the principal sulphides. Some

arsenopyrite is present, and chalcopyrite is recognizable on a polished surface. The gold content of the vein is not known. So far as could be observed, the vein is structurally different from most of the other gold lodes of the district in the absence of ribbon rock, and it is mineralogically different from most of the other sulphide-bearing gold lodes in the absence of arsenopyrite and the presence of pyrrhotite and chalcopyrite.

A vein of quartz has been opened by a trench 10 feet long and 2½ feet deep on the south bank of Big Hurrah Creek about half a mile above the mouth of Little Hurrah Creek. The trench is now so filled with wash that the vein can not be seen. The dump shows mica schist of the Solomon schist and iron-stained quartz vein material, including lenses of schist. The opening is near the contact of the Solomon schist and Hurrah slate. The bedrock schist is a highly quartzose mica schist with probably some chlorite. The vein is made up of large, well-defined crystals, many of which show good terminations and comb structure. Several reopenings of the vein are recorded in one hand specimen. The schist at the contact appears to be silicified, and open texture along the contact is the rule.

The Big Hurrah lode was discovered in 1900, opened up in 1903, and then equipped with a mill and operated on a productive basis until 1908. Since then the property has been idle, and at the time of the writer's visit the underground workings were for the most part inaccessible. Smith's description[42] of this lode is the primary source of the following notes, but they also include some supplementary observations made on the surface exposures and open cuts near the mine. This deposit is one of the few auriferous lodes on Seward Peninsula whose continuity and structural relations are known by extensive underground openings.

The Big Hurrah quartz veins are about the only veins of any great size and proved continuity known on Seward Peninsula. They are several feet in width and are not subject to the pinch and swell and extreme irregularity that have been found to be characteristic of most of the veins on the peninsula. The reason for the difference in the habit of these veins lies in the character of the country rock—the Hurrah slate, a brittle rock that fractures readily and breaks along sharp, clean-cut lines. These physical properties of the slate are not found in the schist and limestone formations that form the bedrock of most of the peninsula, and even the limestones lend themselves less readily to this form of opening.

The three quartz veins that form the lode are roughly parallel in strike. Two of them dip to the southeast and the other to the northwest. They crop out on the bank of Little Hurrah Creek, have been followed by underground workings for several hundred feet to the

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[42] Op. cit., pp. 143-147.

south, and are 4 to 8 feet wide. Considerable prospecting has been done west of Little Hurrah Creek and north of Big Hurrah Creek in the black slate area, in the hope of finding the continuation of the veins or others equally favorable to mine. Little success has attended such attempts, and to date the veins are known only within a very small area of slate between the forks of Big and Little Hurrah creeks.

The main developments at the Big Hurrah mine have been by means of an incline shaft, which has a general though not constant slope of about 60°. The strike of the veins is northwesterly, and the dip is to the southwest. The upper portion of the vein has also been worked in part by adits run in from the outcropping of the vein on Little Hurrah Creek. A general plan of the underground workings is shown in figure 10.

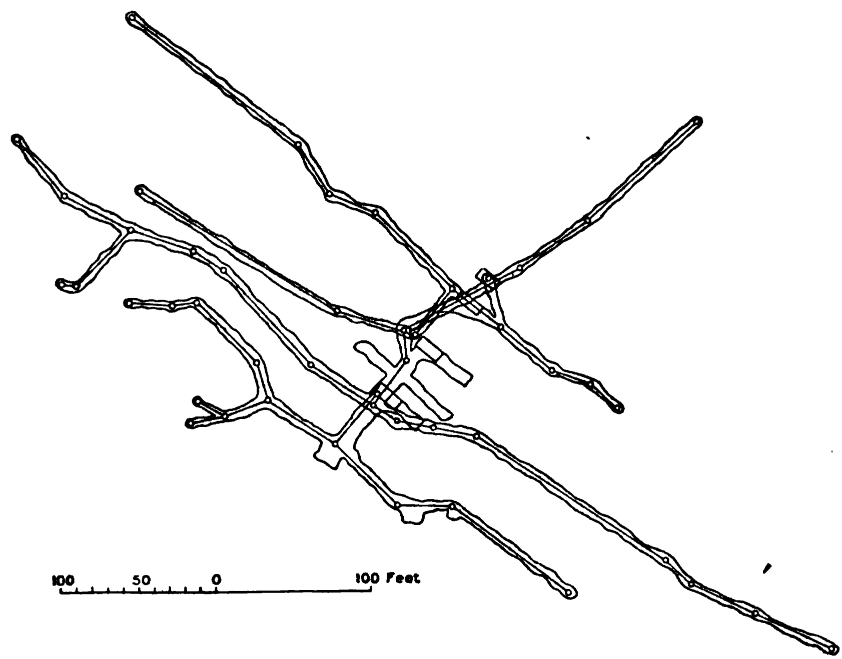

FIGURE 10.—Plan of underground workings of Big Hurrah mine.

North of the main lead there is another vein about 50 feet below in the footwall. This vein, unlike the two farther south, has a northwesterly dip, although the strike is essentially the same as the others.[43]

It was at one time a question with the operators of the property whether the opposite dipping lodes were two distinct veins or limbs of an anticlinal fold. There seems to be no evidence to support the latter theory, and the general attitude of the formation and its minor structural features seem to point to their being two distinct veins.

If the underground conditions at the mine could be studied or the discoveries made during the development work learned, considerable data would probably be available upon which to base a conjecture

[43] Smith, P. S., op. cit., p. 145.

concerning the probability of finding these or similar veins beyond their present known limits. As such data are not to be had, only surface observations can be made. Examination of the open-cut exposures is far from satisfactory but seems to justify certain generalizations. On the east side of Little Hurrah Creek the slate is badly fractured but not appreciably folded. The slate cleavage here strikes N. 10° W. and dips 45° S. Jointing here is the common structure; it is very pronounced and complex. Joints traverse the slate in all directions and with dips extremely variable in direction and amount. The following series was observed on one face:

Strike N. 75° W.,	dip 45° N.	Strike N. 75° W.,	dip 65° S.
N. 25° W.,	65° E.	N. 80° W.,	45° S.
N. 40° E.,	40° S.		

Dips in the slate have little significance, as they are very local and variable. Dislocation along the joints was probably accompanied by tilting of the blocks, so that exposures within a few feet show dips at variance.

On the west side of Little Hurrah Creek the general attitude of the slates is markedly different. Here folding rather than jointing is the characteristic structure, and both gentle open folds and close abrupt folds may be seen. Jointing is of course present, but it is not the predominant structure.

The most pronounced fold observed is exposed in a small drift along the creek bank. A quartz vein 8 inches wide conforms with the fold and is therefore later than the folding. The fold resembles a drag fold along a fault. The strike of the fold is north and the dip west. At another locality 30 feet downstream a second drift exposes a 4-inch quartz vein. The slate here too is folded, and the fold pitches west. The quartz vein is later than the folding and well illustrates the attitude and extreme irregularity of many of the veins that have not followed well-defined joint planes.

Some evidence was obtained at this locality to show that there was more than one period of intrusion of the later quartz veins, separated by a period of slight deformation. There is also evidence of two systems of folding—one comprising open folds whose axes strike east and the other comprising closed folds and faults that strike north. What is believed to be a fault belonging to the northerly system follows the course of Little Hurrah Creek. Differences were noted in the general type of predominating structure on the east and west sides of the creek and also the presence of what are probably drag folds along the creek bank on the west side. These features denote that the west is the downthrown side of the fault. The failure to find an extension of the lodes west of Little Hurrah Creek may be due to this supposed fault.

Concerning the probable extent of the veins to the southeast more conclusive evidence is to be had. As shown on the geologic map (fig. 9) the Hurrah slate forms the country rock for about 1 mile south of the mouth of Little Hurrah Creek and a quarter of a mile to the east, where it is in contact with the Solomon schist; such relations in themselves indicate fault contact. Pits dug along the strike of the veins to the southeast have exposed Solomon schist in the area mapped as black slate. On the basis of this evidence, the veins can not extend in black slate country rock for more than 800 feet, and to judge from outcrops in the creek bank the distance is probably less. The favorable character of these veins is so evidently due to the physical properties of the slate formation in which they occur that they can not be expected to continue into the Solomon schist and persist in their present form, for the schist is decidedly less hospitable to vein formation.

It is not known whether the faulting at the slate and schist contact was earlier or later than the intrusion of the quartz vein. If the veins are older than the faults, as the schist is the older formation and separated from the slate by several hundred feet of Sowik limestone, the schist indicates a relative upward displacement of 400 feet or more. In this case the slate with its contained veins has been removed by erosion, and its gold has gone to supply the local placers. If the intrusion of the veins was later than the faulting they probably never existed in the schist as the well-defined veins that have been mined in the slate area.

The ores of the Big Hurrah mine were free-milling and are said to have averaged less than $20 a ton in gold. Ore of two types was mined—quartz-vein material and ribbon rock—and the latter is reported to have yielded the better returns. Ribbon rock, as the term was here used, included rock showing alternate roughly parallel laminae of quartz and slate, also slate cut in all directions by many small contemporaneous veinlets of quartz, which in places formed more than 50 per cent of the mass. This banded rock was probably due to reopening of the vein and repeated injection of quartz. The other type probably represents shattered wall rock of the vein. The veinlets are as a rule clean cut but locally show curving and ramifying tendencies. The slate consists essentially of quartz with abundant graphite, considerable white mica, and limonite, which give to the rock a very fine lamination. The ribbon rock ranges from quartz with occasional fine laminae of slate to slate with a minor content of quartz.

The vein rock is coarsely crystalline vitreous white quartz of the later-vein type, showing cavities into which well-terminated crystals project. The small veinlets of the ribbon rock are of the same open-textured vein type. In some of the veinlets the quartz crystals

project from one wall only; in others the fissures are incompletely filled by crystals projecting from both walls. A little white mica is the only other constituent of the veins observed microscopically, but decomposed feldspar was seen in some hand specimens and is probably a minor constituent of the vein. The quartz is strained and in places shattered. Fissures through the quartz filled with later quartz give further evidence of movement and more than one injection of quartz. Native gold can occasionally be seen in hand specimens. Microscopically it is seen to occur with the quartz of the vein. Sulphides are almost absent. Neither the sulphides of the vein nor the carbon of the schist were observed to be associated with the gold.

The Gray Eagle claim, an antimony prospect, is on the north bank of Big Hurrah Creek about 1 mile from Solomon River. A 12-foot shaft has been sunk and several trenches dug on a 4-foot quartz vein which carries stibnite. The country rock is the Hurrah slate. The workings are now caved, and the vein is not exposed. No work has been done here for five years. The claim is owned by E. W. Quiggley, who reports the vein to be 4 feet wide and to strike about N. 45° E. and dip 45° N. The stibnite is said to occur throughout the width of the vein. The center of the vein for a width of 1 foot is said to be almost pure stibnite, and the sulphide to occur in nests through the rest of the vein.

Specimens from the dump show the ore to be an intimate admixture of stibnite and quartz crystals occurring through the quartz of the vein. Columnar crystals of stibnite an inch in maximum size occur with clear, glassy, well-terminated crystals of quartz half an inch or less in width. The quartz of the vein, which is free from stibnite, is of the open-textured later-vein type. The material examined did not show definitely the relation of the sulphide to the vein, but it is probably later.

Near the top of the hill northeast of the mouth of Big Hurrah Creek considerable work has been done on the Flynn gold quartz vein. Here there is an inclined shaft, said to be 60 feet deep but now filled with water. Probably 20 smaller shafts and trenches, some of which are 50 feet long and 3 to 8 feet deep, show quartz on the dump, but no vein is exposed. The country rock is the Hurrah slate. In addition to quartz, a green mineralized rock occurs on the dump of a shallow shaft, now filled with water. The rock is composed of fresh arsenopyrite and a very little quartz in a mass of chloritic material such as forms the green rock of the Bluff lodes. Much of the quartz on the dump is of the ribbon-rock type. It is iron stained, but no sulphides were observed. The size, attitude, and relations of the vein could not be seen or learned, as no one is on the property and no work has been done for five years.

Two other prospects within the basin of Solomon River but outside of the area included in the map (fig. 9) will be briefly mentioned.[44]

On the first tributary to Solomon River from the west below East Fork an adit has been driven on a vein occurring in the black graphitic slates. This vein is located along a fault which has an indeterminate throw and is distinctly later than the fault. The amount of mineralization is not very great, although in places the rocks are considerably iron stained. The adit is only 20 feet long, and the mineralization becomes progressively less toward the breast, and the amount of drag indicated by the wall rocks also diminishes. No work has been done at this place for some time.

Several openings have been made on lodes on West Creek, which flows into Shovel Creek, a westerly tributary of Solomon River. These occurrences are described by Smith[45] as follows:

A series of veins occurring in the chloritic-schist areas away from any contacts with other rocks has been opened on West Creek 2 miles above the mouth. Some work is done here every year, and there are 600 or 700 feet of underground workings, but the mine has not yet shipped any ore. The development is on a north-south vein, which was opened by an adit that drifted along the vein for over 350 feet. In this drift both walls were decomposed chloritic schist, which in places showed marked slickensiding. Another adit about 300 feet long has been driven on a vein farther west, which shows the same general character as the first. A crosscut following a small cross stringer has been run from the eastern drift. The quartz from all the veins is practically the same in character. It is white and somewhat shattered but is apparently not sheared nor folded and presumably belongs to the later set of veins. In addition to the quartz the veins carry abundant chlorite and a small amount of pyrite and marcasite. The later metallic minerals occur in small stringers and vugs. The wall rocks are also said to be gold bearing, and the footwall schist is reported to carry from $8 to $10 a ton in gold, but no assays of the rock have been made by the Survey.

COUNCIL DISTRICT.

The Council district has been a large producer of placer gold for 20 years. No valuable metalliferous lodes have been developed in the district—in fact, very few lodes have been found. It appears that a large part of the placer gold is derived from mineralized zones in which the metal has not been sufficiently concentrated to form lodes of commercial value.

The rocks of the district include limestone and schist of various types with a little slate. These rocks strike northeast and almost invariably dip southeast at angles of 25° to 45°. A belt of massive limestone forming the ridge west of Ophir Creek is the only well-defined unit of the district. The bedrock of the rest of the area consists of schist and limestone in varying proportions. On the accompanying sketch map (fig. 11) these rocks have been differentiated into a series in which the schist and limestone occur in about equal proportion, and a series which is largely schist with only subordinate amounts of limestone. The sequence of these beds, if indeed they are distinct formations, has not been established.

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[44] Smith, P. S., op. cit., p. 148.
[45] *Idem.*

The larger features of the geology are not complex, and the uniform southeasterly dip suggests a simple monocline. There are, however, many shear zones in which some of the limestone has been altered to calcareous schist, so that it is difficult if not impossible to trace beds and groups of beds for any considerable distance. It is not impossible that the apparent monocline may actually be an overturned fold, perhaps accompanied by thrust faults, though no

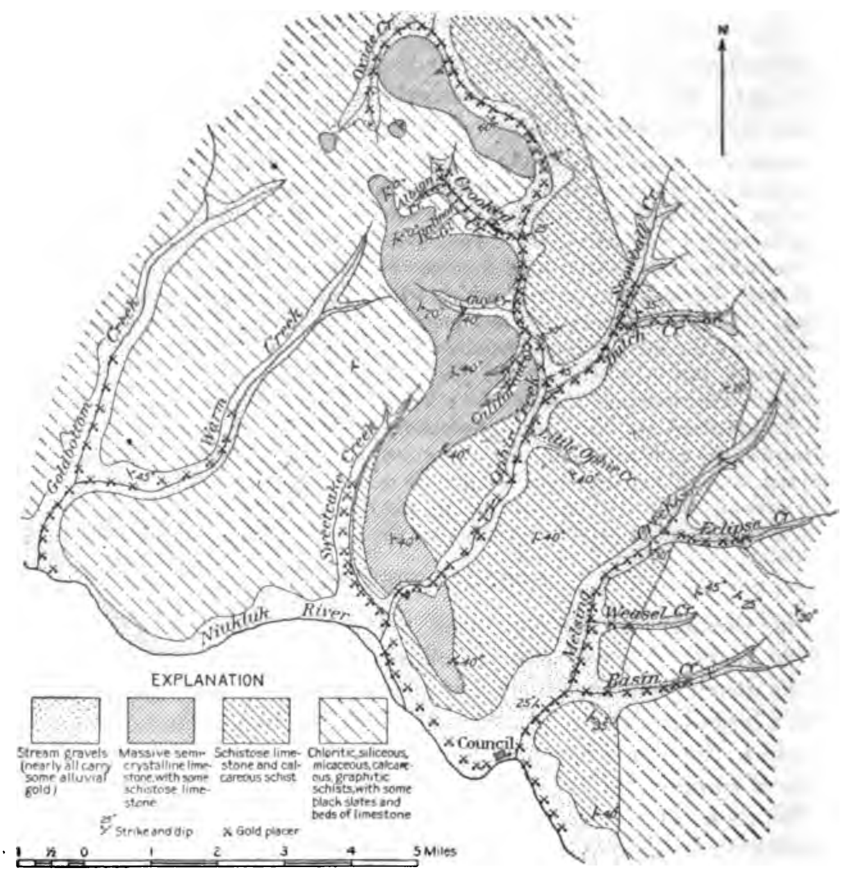

FIGURE 11.—Geologic sketch map of part of Council district.

evidence of faulting was found. The map also shows the approximate distribution of the stream gravels. Practically all these gravels carry a little gold, but it is only in certain localities that these auriferous gravels are rich enough to afford valuable placers.

Few lodes that have encouraged hard-rock prospecting have been discovered in the Council district. The mineralization of the country rock from which the very rich placers of Ophir Creek have been derived does not seem to have been sufficiently concentrated at any

locality to form a lode, but rather the gold has been disseminated throughout the bedrock. Quartz stringers and sulphides are very common in the schist and limestone, especially in the schist. The quartz is known to carry gold, as some of the veinlets are reported to show a gold content on assay and quartz is frequently found attached to gold in the placers. That quartz is the only carrier of gold in the district has not been proved. Some gold may occur with the sulphides, but its presence has not been demonstrated. It is perhaps safe to assign most if not all of the gold to the quartz veinlets, as the sulphides are almost entirely pyrite, and the gold that occurs with sulphides elsewhere on the peninsula is associated with arsenopyrite or stibnite.

The nature of the occurrence which would permit the gold to be so generally distributed throughout the country rock and not tend to produce lodes has been discussed by Brooks,[46] who, from his study of the region, has shown the gold to be related to the limestone and schist contacts. The behavior of the limestone and schist series when subjected to intense folding has been discussed on page 171. The shearing incident to such folding is believed to have supplied openings along the contacts of members of the series which differed in resistance to shear, and these openings were later filled by quartz veinlets that carried the gold (fig. 12). The country rock of the Council district was especially favorable for this mode of occurrence, either because it comprised a series which was originally very heterogeneous and which consequently offered a great many such contacts or because schist zones had been developed within a massive limestone as the result of the shearing. There is evidence that many of the schist zones have been derived from the limestone, as the schist is mostly of the calcareous variety. All the limestone is somewhat schistose, and the transition from slightly schistose limestone through schistose limestone to calcareous schist is frequently seen. West of Sweetcake Creek and east of Melsing Creek the schist is largely siliceous and limestone is not a prominent member of the series. (See diagram, fig. 12.) Between Sweetcake Creek and Ophir Creek and extending north to Crooked Creek is an area which is occupied chiefly by limestone. Between Ophir Creek and Melsing Creek schist and limestone alternate. The schist is largely calcareous, and the limestone is rather schistose. The schist appears to increase and the limestone to decrease in amount toward the east. Ophir Creek, the most productive creek of the area, flows through that part of the series in which the contacts are most numerous and in which quartz veins are most plentiful. Guy Creek,

[46] Brooks, A. H., The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 123, 1907.

the least productive creek of the area, flows through the massive limestone member of the series and cuts only one schist zone. Crooked Creek and its tributaries are cut through the limestone member and into the underlying siliceous schist, which at its contact

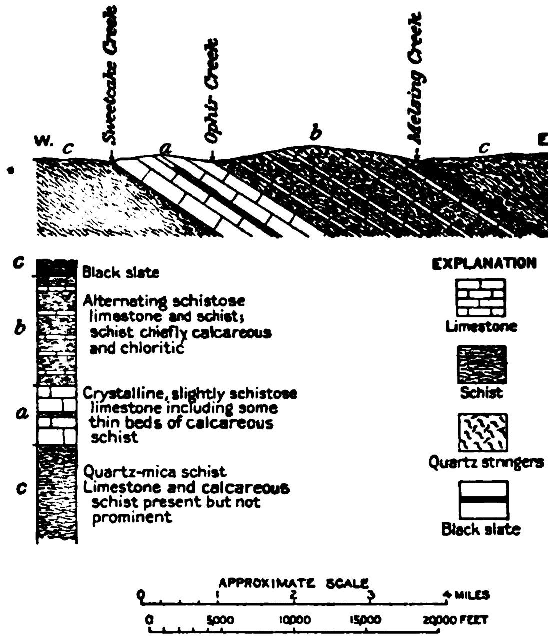

FIGURE 12.—Diagrammatic cross section from Sweetcake Creek to Melsing Creek, showing distribution of quartz stringers, in part mineralized, in schist and limestone.

with the massive limestone is impregnated with quartz veinlets. Sweetcake Creek occupies a similar position with respect to the contact of the siliceous schist and massive limestone.

IRON CREEK REGION.

The Iron Creek region which lies about 35 miles northeast of Nome, has produced a good deal of placer gold, though no very rich deposits have been found. There are also some copper and galena prospects within the district. The bedrock of the district consists chiefly of schist broken by broad belts of limestone which trend in a northwesterly direction. These features are indicated on the accompanying sketch map (fig. 13), but the details of the geology are far more complex than is indicated by this map. The limestone areas are broken by bands of schist. On the other hand, the areas mapped as schist include feldspathic and chloritic schists, as well as considerable areas of black slate and some bands of greenstone, which is of igneous origin. That the placer gold is derived from the schist and limestone

contacts is clearly indicated by their distribution, as shown on the map.

Quartz is not a prominent constituent of the auriferous gravels, and quartz veins are not noticeably abundant in the country rock. The sulphide mineralization was decidedly of the disseminated type, except in the copper prospects. The relations of both quartz veinlets and sulphides to the country rock are much the same as those ob-

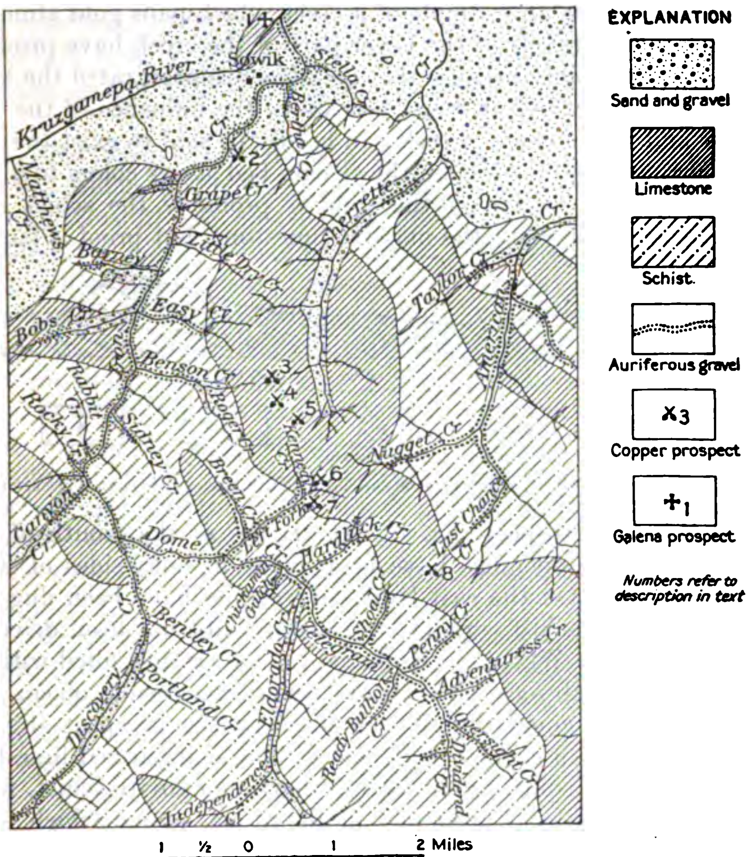

FIGURE 13.—Geologic sketch map of Iron Creek region.

served in the Council district, where schist interbedded with limestone and schist near its contact with heavy limestone were the most susceptible to shearing and the sheared zones offered the most favorable openings for the introduction of gold-bearing solutions. In the Iron Creek region the black slate seemed to have played a part comparable to that taken by the limestone. Both slate and limestone have acted as competent beds, and the schist adjacent to them shows what concentration of mineralization was observed.

Although quartz does not seem to be as abundant in the schist of Iron Creek as at other localities, considerable quartz is associated with the copper minerals in the limestone. This quartz is not known to be gold-bearing, neither is it known that the copper and gold mineralization are of the same age. The younger quartz veins, with which most of the veins in the schist can be safely correlated, have been found by Smith[47] to cut silicified limestone in the Solomon district, presumably similar to that which here carries the copper.

Benson Creek is an example of a creek which pans gold almost to its head. The gravels of the lower part of the creek have produced rather well, probably because the creek has reconcentrated the bench gravels through which it flows, but above the influence of the older gravels and where creek gravels can hardly be said to exist the loose wash surrounding boulders on the stream bed shows colors to almost every pan. The source of this gold is probably the schist zones which occur throughout the massive limestone, but proof is lacking.

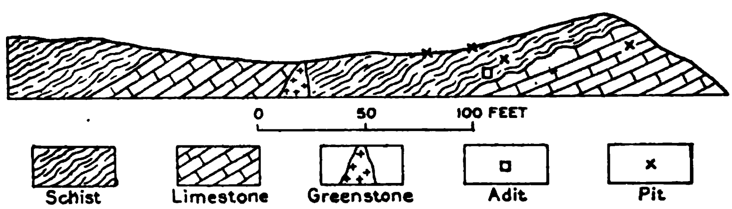

FIGURE 14.—Generalized sketch of exposures on east bank of Kruzgamepa River at Wheeler prospect.

The Wheeler prospect (fig. 13, No. 1) lies at the mouth of Iron Creek, and mine openings have been made in both sides of Kruzgamepa River. On the east bank several pits have been dug near a limestone and schist contact, and a short adit has been driven to cut the contact. Where not timbered the adit is now filled with ice, and almost no wall rock is visible and no ore was seen in place. The section exposed along the river bank near the prospect (fig. 14) shows at the north end 50 to 75 feet of blue marmarized limestone, succeeded to the south by 40 feet of quartz-muscovite schist, which in turn is succeeded by 50 feet of limestone, above which schist occurs. A greenstone, apparently intrusive, occurs at the lower contact of the upper limestone with the schist. The mineralization occurred along the contact of the lower limestone and the schist. The contact shows considerable deformation, the limestone and schist being infolded and the limestone rendered slightly schistose. The beds strike N. 70° W. and dip 10° N.

The schist at the contact shows an abundance of pyrite, but the limestone was only slightly mineralized, if at all. Galena is said to have been found in small quantities, both in the schist and in the

[47] Smith, P. S., op. cit. (Bull. 433), p. 142.

limestone. The ore consists of finely crystalline galena and pyrite in a gangue of quartz and calcite. Some chalcopyrite is also probably present, as malachite stain is seen in places.

On the west bank of the Kruzgamepa two "kidneys" of galena have been uncovered in a schistose limestone near its contact with a chloritic schist. One body of ore has been removed; a part of the other is still to be seen, but its relations to the inclosing rock are obscured by slide. The ore is exposed in an open cut 30 feet long driven northwest on the river bank and 15 feet above the stream. A shaft said to be 22 feet deep, sunk in line with the open cut, did not penetrate the overlying schist and exposed nothing but barren rock.

The mineralized zone is typical of a contact between limestone and schist along which adjustment has occurred. The limestone forms the footwall and adjacent to the schist is highly contorted, crenulated, and closely folded with schist. The limestone itself has become somewhat schistose at the contact, but the extreme deformation extends only 20 feet into the limestone, and beyond this zone it shows its normal crystalline, slightly schistose character. This zone seems to have been a locus of adjustment in the folding at this locality, as other contacts exposed along the river bank show less intense deformation of the limestone.

The ore is not well exposed but seems to have a lenticular form. The section seen was only a few feet in largest dimension. It seems to lie entirely within the limestone and is probably 30 feet or more from the contact. No schist was seen in immediate proximity to the ore.

The ore consists of finely crystalline galena with a little sphalerite and considerable pyrite in a gangue of quartz and calcite. The structural relations suggest that it may have been formed by replacement. Thin sections show that the sulphides occur both in the calcite and in the quartz in replacement relations, but some hand specimens show them as veinlets cutting quartz.

Mr. O. E. Wheeler, the owner, gives the following assay returns on samples of ore determined by Hoover & Strong, Denver. It is not known how the samples were taken: East side, lead 22.87 per cent, silver 20 ounces to the ton; west side, lead 14.2 per cent, silver 14.5 ounces to the ton.

Only a small tonnage of ore is in sight. The ore uncovered has been in disconnected masses along the zone of shearing and offers little encouragement for further prospecting.

The copper prospects of the Iron Creek district have been described by Smith.[48] No commercial ore bodies have been found in this

[48] Smith, P. S., U. S. Geol. Survey Bull. 345, pp. 242-243, 1908.

district, but in view of the mode of occurrence of the copper ores the prospects will be described in some detail.

The mineralization occurred in the limestone that forms the ridge east of Iron Creek. Mineralized rock has been found in a number of places on the ridge between the headwaters of Benson and Penny creeks. Prospecting has been confined to very shallow surface work, except at one locality where a 90-foot shaft has been sunk, and an adit driven. (See fig. 13, No. 4.) The shaft and adit were not accessible at the time of the writer's visit. Although the deposit has not been explored sufficiently to determine definitely the nature of the occcrrence, some of the features observed are worthy of record. The sulphide minerals, chiefly chalcopyrite and some pyrite, occur in quartz which has replaced the limestone and was probably introduced along the bedding planes of the limestone. Wherever observed the mineralized rock is banded, and the banding is conformable with and resembles in detail the banding of the limestone with which the siliceous rock is interbedded. Adjacent to the replaced limestone the normally blue limestone is usually bleached to pale blue or even white. The bleaching of the limestone may produce a banding of colors in the unsilicified and unmineralized rock. In many places beds of limestone show bleaching and recrystallization where no mineralization has taken place. That the bleached aspect of the limestone is due in some way to the process of mineralization and not to lithologic variation in the limestone itself is evident, as it is commonly seen adjacent to the silicified limestone and it is not continuous along the strike of a bed. As the quartz has probably been introduced along the limestone bedding planes the ore bodies can be expected to conform with the structure of the limestone country rock, but this inference can be proved only by underground exploration, though it is supported by all exposures of the silicified and of the bleached limestone where unmineralized. It is probable that here, as observed elsewhere on Seward Peninsula, the major adjustment in the limestone, where it occurs interbedded with schists and has been folded, has taken place along its bedding planes. This adjustment has made the bedding planes the equivalent of fractures and the easiest paths of circulation for later solutions. Fractures transverse to the bedding must also have formed, and exceptions to the bedded occurrence of the veins must be expected. Such an exception is seen near the head of Penny River, but all other exposures observed suggest strongly the bedded occurrence.

Shearing occurred at more than one horizon, and it is practically certain that more than one horizon is represented by the mineralized rock exposed here. The country rock is chiefly limestone, interbedded with which occur beds of schist 10 to 50 feet thick. None of the exposures show positively the relations of the shear zones to the

schist. Schist that carries sufficient malachite to class it as an ore occurs, and copper-stained schist is common. Some specimens of schist ore were seen to carry a little sulphide. Although the silicified limestone observed is interbedded with normal limestone and none was seen at the schist contact, at least some of the openings were probably near the contact.

The silicified rock is of the replacement type that shows many small irregular cavities resulting from shrinkage. Thin sections of the rock indicate that replacement was complete and that quartz is the only gangue mineral. The quartz is shattered and strained and is traversed by sericite and chlorite in small veinlets. Polished specimens show chalcopyrite to be the principal and in places the only sulphide. It occurs in bands roughly parallel to the bedding of the limestone. The bands of sulphide are usually one-eighth inch or less, rarely an inch in width. Limonite surrounds and cuts the sulphides in the surface ores, which are the only ores available for examination, so that the original sulphide content and the relative proportions of sulphide to quartz can not be definitely stated. The fresh sulphide observed occurred within 5 feet of the surface and where seen probably did not form more than a small percentage of the ore. The most characteristic physical property of the ore is its banded structure, which is due to several factors, the sulphides occurring in the quartz and the iron oxide resulting from their decomposition, the shrinkage cavities of the quartz, the banding of the replaced limestone, and the copper carbonates that occur in the openings in the quartz and along the former bedding surfaces of the limestone. All these minerals are roughly alined in parallel arrangement and concordant with the bedding of the unmineralized limestone.

Sulphides of copper are not invariably present where there has been silicification of the limestone. In following one of these croppings along its dip, it may be found that the silica followed certain ill-defined channels along the limestone bedding, as a result of which it will grade laterally into limestone, also that the sulphide is present throughout some parts of the quartz rock and absent in others. The fact that it everywhere shows copper minerals at the surface is due to the presence of the copper carbonates, which will be found to disappear at depth. Although these suggestions are the least favorable that might be offered, they probably represent about what should be expected in developing such deposits. These deposits appear to be of the same type as those developed at Copper Mountain, in the upper Grand Central basin, to be described below.

Malachite is the most common of the oxidized ores, although azurite also occurs. Other secondary copper minerals seem to be absent. A polished surface of chalcopyrite ore shows sulphide surrounded and cut by limonite. Three types of oxidized ore occur—

schist, quartz, and botryoidal malachite. In the quartz-muscovite schist the malachite occurs along the cleavage surfaces and has the same relation to the quartz as the mica. In the siliceous ore carbonates occur as filamentary coatings of fracture surfaces, along planes of banding, and in open spaces through the rock. Some chalcopyrite is present with the carbonates. Crystalline malachite in radial structure with some botryoidal surfaces forms the highest-grade ore known to the miners. Iron oxide is an abundant constituent of all the oxidized ore.

The Wheeler copper prospect (fig. 13, No. 4) is at the head of Sherrette Creek on the east side and near the top of the mountain, near the head of Lula Creek, the north fork of Benson Creek. The development workings consist of several small pits and an adit 200 feet long, driven S. 50° W. to connect with a 90-foot shaft. The adit is now partly filled with ice and completely frosted over, so that no rock can be seen. It was driven in limestone and encountered no ore. The shaft was sunk on a cropping of malachite, which at the surface was 8 feet wide. At a depth of 25 feet schist was encountered, dipping south. The schist is stained by malachite and persisted in the shaft to a depth of 60 feet, where barren limestone was encountered, into which the shaft penetrated 5 feet. No drifting was done. The shaft is now filled with ice.

The only mineralized rock to be seen in place occurs at the open cut leading to the collar of the shaft. Here the limestone is closely folded, marmarized, and in places schistose. It was originally dark blue, but has been bleached white along certain zones and has a banded appearance. Schist infolded in the limestone is stained with malachite and contains some stringers of quartz.

Assay returns on ore from this property shipped to the Tacoma smelter are given by Mr. Wheeler, as follows: The surface malachite, taken above a depth of 20 feet in the shaft, assayed gold, none; silver, 0.33 ounce to the ton; copper, 35.68 per cent; iron, 7.60 per cent; silica, 15.40 per cent. About 8 tons of this material was shipped. Schist ore taken below a depth of 25 feet in the shaft assayed gold, 1.82 ounces to the ton; silver, 5.16 ounces to the ton; copper, 17.18 per cent. About 2½ tons of this ore was shipped. Another shipment of 14 tons was made, but no assays of it are available.

Nothing can be seen of the lode from which this ore was taken, but Smith[49] describes it as a zone of mineralization 5 feet wide in schist. It appears to occur in a schist layer in the limestone. A quartz vein striking north was observed near this copper locality. The quartz is iron stained, but no work has been done on it, so its size and relations are not observable on the talus-covered slope. Two open cuts on the saddle at the head of Benson Creek exposed nothing but lime-

[49] Smith, P. S., U. S. Geol. Survey Bull. 345, pp. 242-243, 1908.

stone. The limestone is blue, coarsely crystalline, and banded by zones of white marble, one-quarter inch to 3 inches wide. It is slightly schistose and badly fractured. The dip is almost vertical. A fault striking N. 25° E. is exposed in one pit. The limestone south of the fault surface is much shattered.

Near the top of the mountain at the head of Benson Creek, south of the saddle (fig. 13, No. 3), a drift has been made in silicified limestone, which shows copper metallization. The workings, which are but 8 feet deep, give the best exposure of the copper ore seen in the district. At the face of the drift the following section is exposed:

Section at face of drift at head of Benson Creek.

	Feet.
Blue limestone	6
Silicified limestone with no copper	1½
Copper ore containing quartz and copper sulphide and carbonate	5
Limestone	1
Blue limestone.	

The mineralized rock is a silicified limestone, the bedding of which is still apparent and conformable with the overlying blue limestone, which strikes N. 10° E. and dips 5°–10° E. Close folding of the limestone is shown in the trench leading to the pit. The face of ore as exposed is an alternation of roughly parallel bands of malachite, quartz, sulphides, and iron oxides. The layers of ore minerals are discontinuous and are interspersed throughout with quartz, without order of succession. They vary from minute films to layers half an inch in width. The sulphide is chiefly chalcopyrite, which is surrounded by iron oxide.

The ore body seems to be related to the bedding of the limestone. It occurs with limestone on both footwall and hanging wall, and there is no indication of vein or lens form. However, it has not been opened along the dip, and this relation is not proved. No schist is exposed, but the folded limestone seen in one trench suggests the usual occurrence at the limestone and schist contact. The section exposed along the ridge between this locality and the shaft is made up of limestone, including a few schist zones 50 to 100 feet thick. The sulphides are clearly related to the quartz, which was probably injected as tiny veinlets along closely spaced bedding shear zones and replaced the adjacent limestone. On the top of the hill, half a mile to the south, four pits have exposed silicified limestone, but only a trace of mineralization was observed. The silicification is here clearly related to shearing in the limestone, as no schist is present.

Three openings have been made on a copper cropping at the head of Sherrette Creek, on the east side of the ridge (fig. 13, No. 5). The pits are shallow and filled with débris, so that no structural data can be obtained. Mineralized quartz and schist occur on the dumps. The mineralization is of the same type as that in the Wheeler prospect.

Two 20-foot cuts have been made in limestone on the west slope and near the top of the ridge, at the head of Left Fork (fig. 13, No. 6). In the more easterly one a little quartz-malachite ore is exposed, some of which carries sulphides. Little can be seen of the structural relations, but the ore appears to conform with the bedding. The only relation evident is that of copper to quartz. The quartz shows many openings, some of which are lined with projecting crystals. The copper carbonate occurs chiefly as fillings of the cavities and coatings on fractures.

About 100 feet northwest of these cuts a pit uncovers a quartz zone conformable with the bedding and unaltered limestone. The quartz is probably continuous with that at the cuts, but here the open texture of the quartz is less evident and almost no malachite is seen—a fact which points to irregularity of mineralization along the quartz zones, dependent upon the texture. This statement applies to the oxidized ore only. As is seen elsewhere, the sulphide content, though irregular, is not related to the open texture.

On the point of the hill near creek level, just above the forks of Left Fork (fig. 13, No. 7), an opening in limestone exposes carbonate ores of copper. Both azurite and malachite are present. The cut is very small, exposing a face of about 10 by 5 feet, so that few structural data are obtainable. The limestone strikes N. 20° E. and dips 25° E. No schist is exposed. The relation of quartz to limestone here is somewhat different from that seen elsewhere. A lens-like mass of quartz lies in general at a slight inclination to the bedding of the limestone. Several small stringers and apophyses from the lens cut the exposed face. The limestone and quartz contact is in places clean-cut, blue massive unaltered and unmineralized limestone adjoining the vein. Elsewhere the limestone near the vein is silicified and the original banding preserved. All the copper minerals seen are associated with the quartz and are oxidized. They coat fractures and occur as a drusy filling of cavities in the quartz.

Although the banded character shown by the ores of the Wheeler copper prospect is evident in some of the material here, the relation of the quartz is more of the vein type. It suggests that the quartz has followed fissures which in general were openings along beds of limestone but in places cut across the limestone beds. The replacement of the limestone was incidental to the introduction of the quartz. Several shallow pits have been made along the ridge southeast of this locality. They have exposed the typical quartz rock, but it shows little or no mineralization.

Several open cuts have been made on a strong showing of the quartz on the west side of the ridge about midway between the headwaters of Left Fork and Hardluck Creek, but there is hardly a trace

of copper mineralization. The character of the quartz body has not changed, the open texture of the quartz and the well-terminated crystals lining cavities are the same, and some decomposed sulphide is disseminated through the rock, but the copper minerals seem to have largely disappeared. The limestone here is shattered and almost schistose. It strikes N. 30° W. and dips south. The exposures show nothing of the relations of the quartz and limestone.

Just south of the saddle between Shoal and Last Chance creeks a 6 by 8 foot shaft 10 feet deep has been sunk on an outcrop of quartz (fig. 13, No. 8). Although exposed for only a few feet along the strike it appears to be a distinct vein and in this respect is different from other exposures. The vein is 5 or 6 feet wide, strikes N. 50° W., and dips west. The limestone 100 yards to the east strikes N. 70° W. and dips 20° S. At its contact with the vein the limestone is altered to a calcareous schist for a width of a few inches. Both schist and limestone show a little sulphide mineralization adjacent to the vein. The quartz is mineralized by decomposed sulphides, some of which were probably chalcopyrite. Very little copper stain is present, however, and the vein is chiefly a slightly iron-stained bull quartz. The silicified limestone does not occur here, the limestone being calcareous to the vein walls.

About 200 yards to the south, at the head of Penny Creek, several openings on quartz in limestone show only very slight copper stain. The exposures do not show the relations. The copper almost disappears southward along the ridge. No further openings or croppings were observed.

On the east bank of Iron Creek about a mile above the mouth of Bertha Creek (fig. 13, No. 2) a small open cut exposes a lode of the type occurring on the ridge at the head of Benson Creek. The material is silicified limestone containing a little sulphide and some malachite stain. The lode occurs in the blue limestone but is poorly exposed and not well defined. It is about 3 feet wide where seen.

About 200 feet north of this locality a vein of coarsely crystalline calcite has been opened. The calcite is cut by veinlets of quartz and contains fresh pyrite in abundance. Some pyrite also occurs in the quartz veinlets. The relations of the vein are not exposed. Both schist and limestone occur on the dump and suggest that the vein is at or near to the contact.

COPPER MOUNTAIN.

Some copper-bearing rock has been found on the two slopes of Copper Mountain, whose drainage is carried southward into Nome River and northward into Kruzgamepa River. This area lies about 25 miles north of Nome. The general features of the geology

are shown on the accompanying map (fig. 15), which is based on Moffit's survey.[50] A broad belt of schist, locally including beds and lenses of limestone, forms the country rock of the mineralized area. To the south the schist is overlain by heavy limestones which include some minor beds of schist. On the lower northern slope of the mountain there is a small area of gneissoid granite, which was intruded in the schist.

So far as it could be determined the copper mineralization was of the same type as that on Iron Creek, already described. The zones of mineralization occur in bleached and in places silicified beds or lenses of limestone which are interlayered with the schist. In these

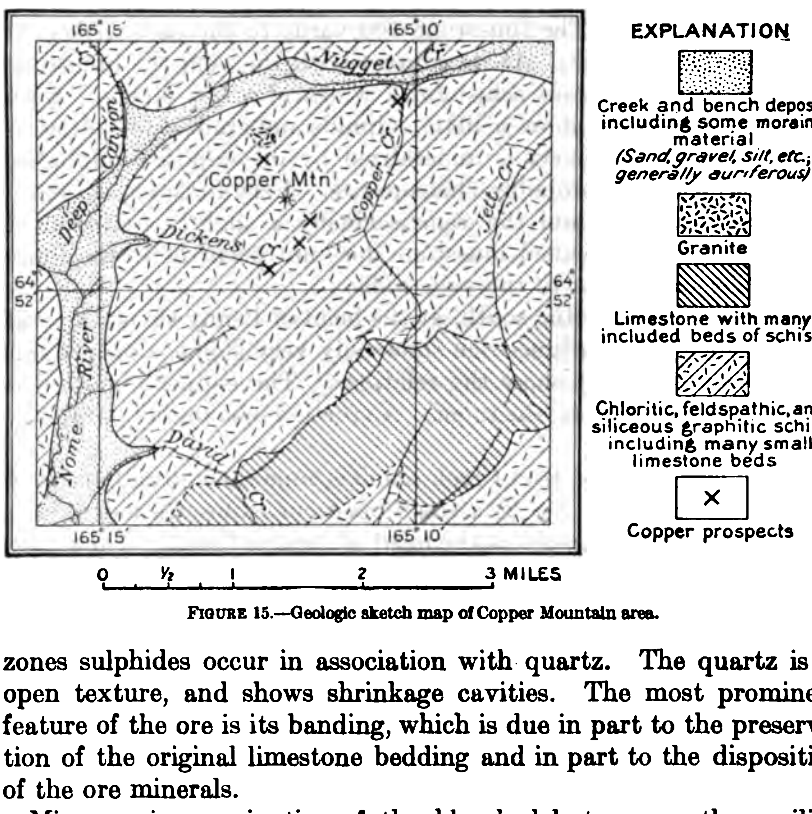

FIGURE 15.—Geologic sketch map of Copper Mountain area.

zones sulphides occur in association with quartz. The quartz is of open texture, and shows shrinkage cavities. The most prominent feature of the ore is its banding, which is due in part to the preservation of the original limestone bedding and in part to the disposition of the ore minerals.

Microscopic examination of the bleached but apparently unsilicified and unmetallized limestone shows it to be practically all calcite. Muscovite occurs in small amounts along bedding planes. Veinlets of quartz that are parallel and oriented with the micas are numerous. Angular crystals of quartz occur through the calcite and are especially abundant near the veinlets. The relations of the quartz suggest

[50] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, 1913.

that it was introduced along cleavage surfaces and replaced the limestone. In the silicified limestone in which copper sulphides occur the replacement is complete, and quartz, with a little mica, forms the gangue of the ore.

Malachite and azurite are the most abundant ore minerals, as the workings have been confined to the oxidized zone. Sulphides occur, however, within a few feet of the surface. Pyrite and chalcopyrite are about equally abundant. Galena is present in small amounts at one of the shafts on Dickens Creek. Bornite is common as an associate of chalcopyrite and in places is the only copper sulphide in the ore. The amount of mineralized rock that might be classed as ore and the details of the occurrence of the ore can not be determined, as the workings are all inaccessible.

The occurrence near the north point of Copper Mountain is of interest in that it is one of the two prospects in southern Seward Peninsula which are in the vicinity of recognizable intrusive granite. A small body of sheared biotite granite crops out on the slope below the tunnel (fig. 15). The granite is rather finely crystalline but shows porphyritic and chilled marginal phases. Small dikes of dense finely crystalline light-green rock cut the mass. Both dikes and granite are cut by later quartz veins. The contact is not exposed, but blocks of limestone in contact with the chilled phase of the granite were seen as float. The limestone is marmarized, and pyrite occurs here and there at the contact, but the rock shows no other evidence of metamorphism. The granite is intruded in schist that is in contact with the silicified limestone in which the mineralization occurred. About 50 feet of schist lies between the granite outcrop and the mineralized zone. No direct relation between the igneous rock and the mineralization was observed. The facts that the mineralized zone is associated with uncrushed quartz and that the sheared granite is cut by undisturbed quartz veins suggest that movement affecting both the sedimentary contacts and the igneous intrusive prepared the openings which are now occupied by the mineralized quartz and the quartz veins, respectively.

On Copper Creek about a quarter of a mile above the railroad several openings have been made in a limestone bed which shows zones of alteration and some copper mineralization. The country rock here is schist, with which occur beds of limestone 50 to 100 feet thick. A fall is formed where the creek crosses the contact and affords an unusually good exposure of the alteration and mineralization of the limestone. The limestone, normally blue, is bleached for a thickness of 12 feet to white or pale bluish white. In places this alteration affects the rock in zones and gives the limestone a banding parallel to the bedding. Both the bleached and the unbleached limestone are coarsely crystalline, and some of the

bleached rock resembles pure calcite. Distortion of the limestone along the contact with the schist was not observed at this exposure. Several zones of schist a few inches thick are interbedded with the limestone, but the rock itself is massive. Two openings have been made in the altered zone at the fall. On the west bank of the creek a 10-foot incline and an 8-foot shaft have cut into but not across the zone. The rock shows little silicification and no copper minerals. On the east bank, 200 feet away from the first opening, an incline has been driven on the same zone. The limestone dips 28° S., and the incline follows the dip. At the time of visit ice filled the opening within 20 feet of the surface. The rock here is banded blue and white, and the bands are from a few inches to a foot or more in width. As a whole it is little silicified, but there are two zones of entirely silicified rock conformable with the bedding. They are 3 and 5 inches wide and separated by a foot or more of unsilicified rock. The quartz rock has a banded character, due in part to the white and blue colors, in part to copper carbonate, and in part to bornite, which with the carbonate seems to occur along former planes of lamination. The mineralized rock appears to be the result of a replacement of limestone and the silica to have been introduced along the bedding planes.

The almost complete absence of quartz in the western prospect indicates a very erratic distribution of this mineral. The presence of unmineralized quartz indicates further restriction of the sulphide mineralization. Where sulphide minerals of this type have been observed, they occur in silicified portions of bleached limestone. The bleached limestone, however, is not everywhere silicified, and the quartz is not everywhere metallized. The next overlying limestone shows only a very little copper stain, although its altered basal portion is as prominent as the limestone just referred to. The upper contact of this bed of limestone is also altered, but without being silicified, so far as observed. There are certainly two zones of alteration here, and probably three, as no surface indications of faulting can be observed.

The neighboring schists are highly mineralized and are cut by veins of the quartz-calcite type. One quartz vein 2 feet wide can be traced for a quarter of a mile on the upper creek. The quartz-calcite veins show sulphide mineralization both in the quartz and in the calcite.

Work has been done on a similar copper showing on the divide between Copper and Dickens creeks. A number of pits, trenches, and shallow shafts have been made on a zone of bleached limestone, which is as much as 300 feet wide, is lenticular in outline, and extends in a N. 40° E. direction for a distance of a quarter of a mile. The openings are now caved or filled with water, and no exposures of

ore in place can be seen. Moss covers the saddle and hillside, so that the stratigraphic relations are obscured, and only mineralized rock from the dumps is available for examination. Chalcopyrite, bornite, and pyrite are the most abundant sulphides. Galena occurs in small amounts at one shaft. Azurite and malachite are present with the sulphides. The sulphide and oxide minerals occur in a roughly parallel arrangement, giving the ore a banded appearance.

This zone is too high stratigraphically to be correlated with the zones of Copper Creek. The circumscribed nature of this type of mineralization is emphasized here by the apparent elliptical form of the area of altered limestone.

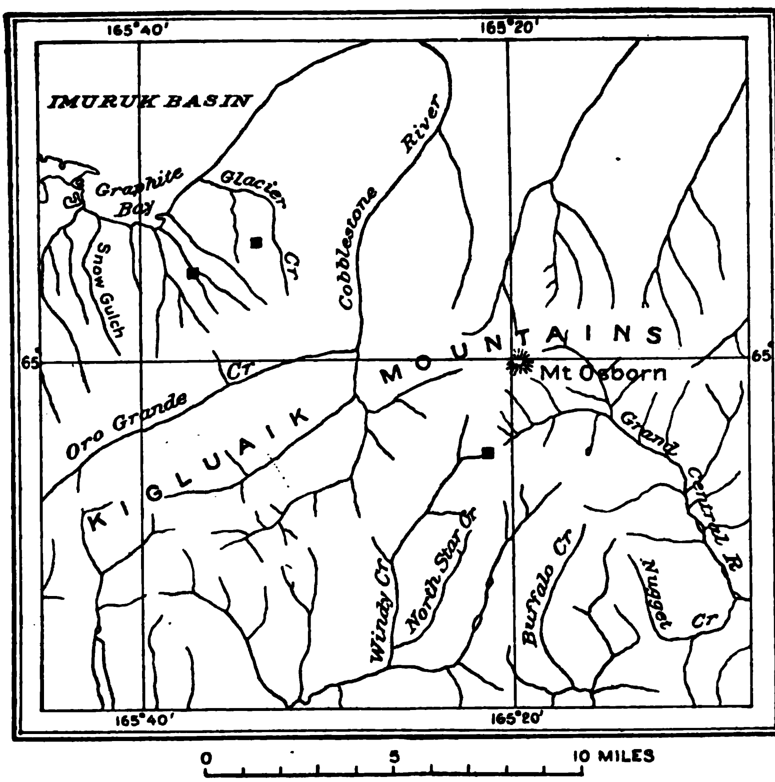

FIGURE 16.—Map showing location of graphite deposits (■) in the Kigluaik Mountains.

GRAPHITE DEPOSITS IN THE KIGLUAIK MOUNTAINS.

Graphitic schists are common in the Kigluaik Mountains, and in many places the graphite is sufficiently abundant to warrant their investigation as possible commercial deposits. Several hundred tons of graphite has been mined on the north slope of the mountains, where commercial ore bodies have been developed on two properties only a few miles from tidewater at the Imuruk Basin. (See fig. 16.) Development work on these two properties is at present

suspended. Harrington[51] has described these deposits as occurring in lenses associated with the schist and gneiss that form the country rock of the northern slope of the Kigluaik Mountains. Such graphitic deposits have been traced for several miles west of Cobblestone River on the outer slope of the mountains and are reported to occur farther in the range. Considerable work has been done on the properties, but most of the graphite shipments have been made from the eastern property, owned by the Alaska Graphite Co., which has built a wagon road to tidewater. The second group of claims is owned by the Uncle Sam Alaska Mining Co. The following description of these deposits is taken from Harrington's report:[52]

The lenses of graphite occur in association with quartz schists that carry biotite, but garnetiferous schists that carry some calcite are also locally present. Some of the quartz schists have the appearance of beds of metamorphosed sandstone. Tourmaline was noted in small grains in the graphite at one locality. Granitic rocks appear to make up a portion of the core of the range. The general trend of the schists in which the graphite occurs is a little north of west and the dip is 60°–75° N. Locally there are two or three series of graphite lenses which are parallel in strike and dip, but it can not be positively stated, without further very detailed studies, that they represent more than one horizon, which may have been repeated by faulting or close folding.

The topographic situation and nearness to water transportation have favored development work at these deposits, in comparison with those which are said to occur for several miles eastward, extending along the front of the range beyond Cobblestone River and appearing on the hill slopes or in the stream valleys which are incised into the range.

* * * * * * *

There appears to be an opportunity for the development of a large amount of graphite from these deposits. Transportation problems are relatively simple. If a sufficient tonnage is mined aerial trams, possibly of a gravity type, might be used from one or both properties. For smaller tonnage good roads could be easily constructed for team or power haulage, and the power required for hauling loads would be small on account of the generally uniform downhill slope to the shipping point. Graphite Bay affords a good shallow harbor, for numerous small coves and islands give protection from storms.

If a mill should be erected at either property hydroelectric installations would probably prove the more economical for summer operations, power being derived from some of the small streams which cross the claims. For winter operations other power would be necessary.

Graphite deposits also occur south of the crest line of the Kigluaik Mountains, where they were long ago found by Moffit,[53] but not being as accessible as those described above, they have attracted but little attention. Such deposits are found in the upper part of the Grand Central basin, where they have an eastern trend. The best

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[51] Harrington, G. L., Mineral resources of Seward Peninsula: U. S. Geol. Survey Bull. 692, pp. 364-366, 1919.

[52] Op. cit., pp. 365, 367.

[53] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pp. 135-136, 1913.

deposit seen in that region occurs on the West Fork of Grand Central River in the schist which overlies the limestone forming Mount Osborn and in which the valley of West Fork is cut. This schist probably belongs to an older series than those which are described in connection with the other deposits and are confined to the mountain area. It is essentially a siliceous biotite schist and is intruded by many igneous sills and dikes. In general it strikes N. 80° E. and dips 15°–25° S.

The best exposure of the graphite-bearing beds occurs along the divide between West Fork of Grand Central River and Windy Creek. The schist includes quartz-biotite, garnet, and graphitic varieties. Some limestone in thin beds and numerous intrusive sills and dikes of granitic rock complete the section.

Most of the graphite occurs as small flakes disseminated through the schist. It is locally segregated in nests of ¼-inch size in the rock, but usually its distribution through the rock is uniform. At some horizons the flakes of graphite are parallel and give a schistose structure to the rock; at others they occur without uniform orientation. The richest of this material is essentially quartz-graphite schist. Where graphite occurs with biotite it is not always easy to distinguish the two in hand specimens, and the material appears to be of much better quality than it really is. The biotite schist is the most prominent member of the series.

BISMUTH DEPOSIT.

A quartz vein containing a little disseminated bismuth sulphide is exposed in the stream channel of the east fork of Charley Creek, a tributary from the south to upper Stewart River. The deposit lies about 25 miles due north of Nome. It does not appear to be of commercial value, so far as can be determined from the exposures, but a description is included here because the occurrence of vein bismuth is unknown elsewhere in the peninsula. The country rock is schist.

The development workings consist of open cuts on both sides of the creek, which expose the vein for a distance of about 50 feet along the strike and 10 feet in depth. Two parallel quartz veins 10 and 5 inches wide, striking N. 80° W. and dipping 50° N., are separated by a foot or more of schist. The quartz is of the open-textured type and shows numerous cavities lined with well-terminated crystals. Microscopically the vein is made up of quartz with a little white mica. The veins have been intruded along joint planes in the chloritic schist country rock, which strikes east and dips 30° S. The wall rock is quartz-muscovite schist containing considerable chlorite and some biotite. A little graphite and pyrite are also present. The veins can

not be traced beyond the creek bottom, the valley sides being covered by moss and talus, and they are exposed here only because the creek has cut a narrow gorge in this part of its course.

No ore was seen in place. A small quantity of mineralized quartz on the dump contains bismuthinite, occurring in tiny veinlets through the rock. Cross veinlets concentrated here and there form dark patches in the white, opaque vein material. There is no means of estimating the sulphide content of the vein, as the portion now exposed was not seen to contain any. The mineralized material on the dump contains only 1 or 2 per cent of sulphide, and the metal content of the vein is probably very small. The vein has been reported to contain platinum in considerable amounts, but reliable assays made for the Geological Survey show no trace of platinum.

ANTIMONY DEPOSITS.

Antimony in the form of stibnite is rather widely distributed on Seward Peninsula.[54] It occurs at several localities in the vicinity of Nome, in the Manila-Lost Creek area, described below, on Big Hurrah Creek in the Solomon district (p. 204), in the York district,[55] and at the Omalik mine, in Fish River basin.[56]

The deposits in the Manila-Lost Creek area have thus far proved to be of the most importance. A number of antimony-bearing lodes have been found in this area, which lies about 20 miles north of Nome. Here the southward drainage goes into Nome and Snake rivers, and the northward drainage into Stewart River. As shown on the accompanying map (fig. 17), which is based on Moffit's survey, the country rock consists of a great series of schists, with some interbedded limestone, which is overlain by a heavy limestone formation that also includes some beds of schist. These rocks are cut by a few granite stocks and dikes.

In the vicinity of Manila Creek a number of antimony-quartz lodes, some of which are gold-bearing, have been prospected. At the Hed & Strand mine, on Dahl Gulch, a tributary of Lost Creek, and at the Sliscovich mine, on Manila Creek, considerable development work has been done and some antimony ore has been produced. The Hed & Strand property has been described by Mertie,[57] and the Sliscovich by Chapin.[58] Little or no progress has been made since their visits. A number of other prospects have exposed ore between Cold Creek and Manila Creek and on the divide between Manila and Hobson creeks, but the workings are shallow, and except

[54] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 50, 59, 1916.
[55] Knopf, Adolph, Geology of the Seward Peninsula tin deposits: U. S. Geol. Survey Bull. 358, 1908.
[56] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 131-133, 1911.
[57] Mertie, J. B., jr., Placer mining on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 436, 1917.
[58] Chapin, Theodore, Lode development on Seward Peninsula: U. S. Geol. Survey Bull. 592, p. 403, 1914.

for ore on the dump show nothing concerning the occurrence of the antimony.

The ores of this locality are typical of most of the antimony ores of the peninsula. In the area examined the stibnite is commonly associated with the later quartz veins. Kidneys of stibnite accompanied by very little quartz have been found along shear zones in

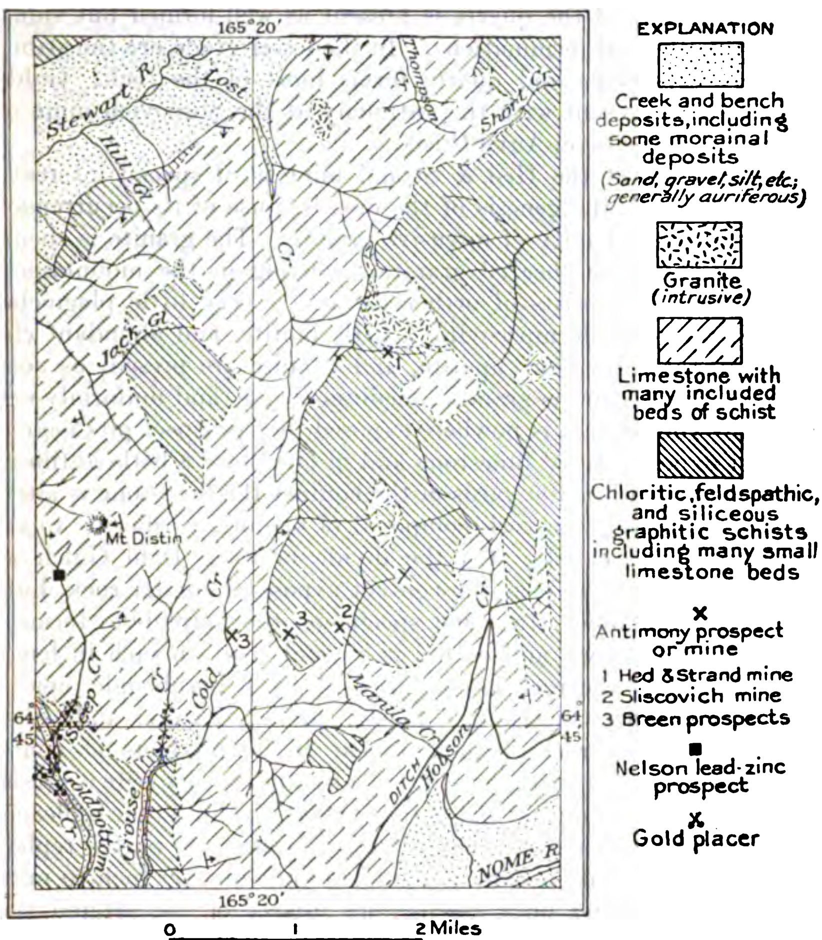

FIGURE 17.—Geologic sketch map of Manila-Lost Creek area.

schist at the Boulder lode on Waterfall Creek (p. 231), and in the Winsted tunnel on Anvil Creek (p. 238), but the ore bodies are small.

Where associated with the quartz veins the stibnite seems to have been introduced since the formation of the veins. Apparently after the intrusion of the quartz veins movement continued to take place along the vein fissures and they were reopened and the veins shat-

tered. Antimony-quartz solutions were then introduced.[59] At some localities the stibnite occurs as irregular bodies between the vein and its schist wall and as nests and stringers in the vein itself, but at most localities it is present only as veinlets in the quartz.

The stibnite is usually accompanied by some pyrite and a variable amount of contemporaneous quartz. In the purest specimens the stibnite occurs as distinct acicular crystals, some of them an inch or more long, and the quartz is present as well-formed but smaller crystals with good terminations. In the lower-grade ore the stibnite is finely crystalline and quartz forms most of the rock. Gold is known to be present with the antimony at the Sliscovich mine and at several deposits on Anvil Creek.

The deposit at the Hed & Strand mine is of special interest in connection with the genesis of the ores because of its occurrence in the immediate vicinity of intrusive granite. The granite is sheared and resembles the sheared granite occurring in the mountains to the north. It consists of orthoclase and a very little plagioclase, quartz, considerable muscovite, a little biotite, and abundant chlorite. Magnetite, zircon, apatite, and titanite are present as accessories. The texture is granitic, medium coarse, and uniformly crystalline. The contact is nowhere exposed, but prospect pits near the contact expose altered limestone and in one place a little antimony.

In one pit within 100 yards of the contact the limestone is altered to a dense light-green rock composed of epidote, cordierite, quartz, muscovite, and calcite. On the divide between Dahl Gulch and Dorothy Creek a pit near the contact exposes a similar rock, but it contains amphibole. In some specimens the amphibole forms 50 per cent of the rock and occurs in crystals half an inch in length. Microscopically the rock is composed of green hornblende, epidote, zoisite, cordierite, muscovite, quartz, zircon, titanite, and calcite. Neither of these rocks, which appear to be products of contact metamorphism, contains any stibnite, although some pyrite is present. In another pit, within 100 feet of the contact, the limestone is bleached and coarsely crystalline. The altered limestone is partly replaced by quartz. Stibnite occurs in veinlets of one-quarter inch to microscopic size, cutting both calcite and quartz of the altered rock. Pyrite is abundant, and malachite is present in small amount. Both occur in or coating fractures. Calcite veins are numerous in the limestone, and one vein was seen to contain a crystal of stibnite 1 inch long.

Although the data obtainable do not afford definite proof, it is probable that the epidotized limestone is the result of contact metamorphism. It is not certain, however, that the stibnite is in any way related to the granite. Stibnite is not seen to occur with the

[59] This interpretation of the facts has already been made by Brooks (Bull. 449, p. 52, 1911).

contact rock. It is present with the silicified limestone but is of later origin than the alteration of that rock. It is probable that an opening was formed at the granite contact, along which the stibnite solutions entered. Further evidence that the antimony mineralization was not related to the granite is found in the structural relations. The granite has been badly sheared. The age of greatest movement in the rocks of the region antedated the formation of the quartz veins, later movement shattered these veins, and the stibnite was then introduced. Some movement has occurred along the veins since that time, but it has probably been slight, as even the soft stibnite ore has been little affected by it. The time of antimony mineralization would therefore seem to be much later than the intrusion of the granite.

The structural features observed in the Sliscovich and Hed & Strand tunnels, as well as the strike of these two well-defined lodes, indicate a parallelism with the dominating structure of the Kigluaik Mountains to the north. These features are probably related to the later deformation of the Kigluaik rocks. The smaller features of this period of folding probably determined the openings along which antimony mineralization took place.

The Hed & Strand antimony mine is on Dahl Gulch, a tributary of Lost Creek, which empties into Stewart River (fig. 17). A 250-foot tunnel has been driven near creek level in a direction S. 40° E. Drifts have been run 145 feet southwest and 520 feet northeast along the main vein, which is intersected 90 feet from the entry. At 200 feet from the entry a drift has been run 190 feet northeast. A winze has been sunk in the tunnel 60 feet from the entry, and a raise driven from the 520-foot drift. Some stoping has been done on the vein, and numerous surface pits and trenches have been dug in the vicinity of the mine. Shipments of ore were made in 1915 and 1916, totaling 106 tons, and a few tons remain on the dump.

At the time of the writer's visit little could be seen of the ore relations. Stibnite has been mined only from the main vein, where it occurred in shoots. The shoots encountered by the present workings have been stoped out, so that only the least productive part of the vein is now exposed. The vein strikes N. 65° E. and dips 50° NW. According to Mertie,[a] the vein where intersected by the tunnel was 4 feet thick and consisted of white quartz and stibnite. The stibnite occurred as a body 2 feet thick along the footwall. As exposed along the drift the vein shows repeated pinch and swell. Where not stoped the vein is present only as a thin stringer and in places seems to disappear entirely. Near the end of the northeast drift the quartz has a gray color, due to finely crystalline stibnite, occurring in tiny veinlets through it. Elsewhere it contains only pyrite in veinlets.

[a] Mertie, J. B., jr., Placer mining on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 437, 1917.

At the end of the northeast drift a 2-inch quartz vein intersects the drift at an angle near 90°. An eighth of an inch of pyrite occurs between the quartz and the wall rock. Specimens of massive arsenopyrite, said to come from this locality, were shown to the writer and are reported to be silver-bearing. This veinlet does not seem to be related to the main vein. In the southwest drift near the adit a small amount of ore remains at the edge of a stope. Two types of ore are present—quartz vein material cut by veinlets of stibnite and acicular stibnite including crystals of quartz. The quartz is here frozen to the footwall and is 2 inches thick; 1 inch of gouge separates the quartz from 1 inch of stibnite, and 3 inches of gouge occurs between the stibnite and the hanging wall. The stibnite is evidently later than the quartz vein and has been introduced along the hanging wall, filling fractures in the quartz vein and occupying open spaces between the vein and the hanging wall. Later movement along the vein has broken the contacts between the quartz and stibnite and between the stibnite and the hanging wall.

The wall rock is chlorite schist, and the hanging wall is everywhere slickensided. At the end of the southwest drift the footwall is altered to sericite schist and is highly mineralized by pyrite. This alteration was not seen to be common.

The drift running northeast at 200 feet from the entry exposes little. It follows a stringer of quartz one-fourth inch to 4 inches wide. The walls are slickensided and in places show gouge. No antimony was seen. At 30 feet from the adit the drift intersects an 8-inch quartz vein, which is offset 2 feet in crossing the drift.

A zone of antimony-quartz mineralization appears to extend from the divide between Hobson and Manila creeks to Cold Creek. The relations of the lodes to the geology can be made out only at the Sliscovich mine, for little can be learned from the surface. The steep slopes are covered with coarse talus of chlorite and feldspar schist; the gentle slopes with moss. Quartz float is abundant through the talus, and a number of veins are probably represented.

At the head of the right fork of Manila Creek a quartz vein not fully exposed but apparently several feet wide strikes S. 80° E. and dips 40° S. It was located by Joe Sliscovich as a quartz lode. No evidence of mineralization was observed, and almost no work has been done on the property.

Just east of this exposure, along the strike of the vein, several pits have exposed quartz which shows mineralization and structure similar to those of the copper ore of Iron Creek and Copper Mountain. It is an open-textured banded quartz rock which contains abundant sulphide, chiefly pyrite, and some malachite stain. The source of this material is not clear. It is not exposed well enough to indicate

whether it is a vein or rock in place. Its isolated occurrence suggests that it might be a drift boulder derived from the ridge above.

The ridge at the head of the right fork of Manila Creek consists of limestone underlain by schist. Several pits along the contact zone expose bleached limestone and in places a calcareous muscovite schist stained by malachite. The copper stain is associated with the mica, and the rock is similar to the schist ore of Iron Creek. The quartz rock referred to above may have originated along this contact, although the bleached limestone exposed at the contact is not noticeably silicified or metallized.

A hundred yards southeast of the copper-stained rock on the ridge several openings have been made on antimony ore. The veins were not exposed at the time of visit, but ore on the dump shows that the mineralization was essentially the same as at the Hed & Strand mine, the rock consisting of quartz cut by veinlets of stibnite. The country rock is chlorite schist.

The Sliscovich antimony-gold mine is near the head of Manila Creek (fig. 17). Details of the occurrence are reported as follows by Chapin,[61] who visited the property in 1913:

> This property was staked in 1905. The vein, which strikes N. 60° E. and dips 45° NW., was traced on the surface for over half a mile, nearly across the basin of Manila Creek. Besides a number of prospect pits two openings have been made to develop the lode. A short distance below the point of discovery a 50-foot adit was driven to crosscut the lode, but no further work was done at this place. The main opening is at an elevation 100 feet lower. There an adit was driven 315 feet to the lode, which was opened by an inclined shaft for 100 feet.
>
> The lode is composed essentially of dull, opaque quartz and stibnite, the sulphide of antimony, in approximately equal amounts, although slight variations in the proportions of the two minerals appear from place to place. Near the surface the antimony predominates, and in places nearly pure stibnite occurs in small bunches. A number of assays and analyses have been made on samples of the ore, all of which show rather constant antimony, gold, and silver. An analysis made on a small shipment of ore said by the owners to have been obtained by accurate sampling of the vein was submitted for chemical determination and showed the following:

Gold and silver not published.

Antimony (Sb)	35.05
Sulphur (S)	13.79
Silica (SiO_2)	48.80
Molybdenum (Mo)	None
Qualitative arsenic (As)	None
Wet lead	Trace
	97.64

Lime and magnesia present but not determined quantitatively.

No development work has been done on the property since Chapin's visit. In 1915 the high price of antimony induced the mining of the antimony portion of the vein. A stope was begun about 30

[61] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, pp. 403-404, 1914.

feet from the bottom of the shaft, driven 30 feet to the north and 40 feet to the south along the vein, and extended within 25 feet of the floor of the adit. Only rock containing high percentages of stibnite was removed, and the waste incident to such mining was dumped into the shaft. The stopes were not well timbered, and the roof is sloughing, so that only that part of the vein at the upper limit of the stope can be seen.

Where the vein is intersected in the adit it is only a few inches wide. At a depth of about 25 feet in the shaft it swells, and this is the portion that has been removed. At one place it was seen to consist of 13 inches of stibnite and 32 inches of quartz. It appears to be a compound vein similar to the Hed & Strand vein, consisting of a quartz portion on the hanging wall through which occur veins and nests of stibnite, and a stibnite portion on the footwall in which the stibnite includes some quartz. Gouge occurs on both walls and between the two portions of the vein.

The relative proportion of the quartz and stibnite phases of the vein varies from place to place. The stibnite portion is said to thin out entirely in places, but the quartz portion to persist. The quartz phase may show almost no stibnite, a little, or much. Some nests of very pure coarsely crystalline stibnite occur through the vein. The antimony mineralization was clearly later than the introduction of the gold-bearing quartz vein.

Few structural data can be had from the working, due to timbering, frosting, and sloughing of the walls. A number of fractures can be made out, striking N. 30°–60° E. and dipping 45°–80° W. Gouge marks some of the surfaces, and several are filled by thin seams of quartz. One fault surface, almost horizontal, extends for 150 feet. The wavy character of the surface is noticeable. Here as elsewhere irregularity seems to mark the fractures in schist and is reflected in the pinch and swell of the veins.

An opening has been made on an antimony-bearing quartz vein on the ridge west of Manila Creek, about half a mile south of the Sliscovich mine. A shallow shaft is now caved, and the ore is not seen in place. To judge by the material on the dump, the vein is probably not more than 8 inches thick.

A number of openings have been made on antimony veins by Henry Breen, who has staked six claims between Clear Creek and the divide between the right fork of Manila Creek and Hobson Creek. (See fig. 17.) Several trenches and pits on the east bank of Clear Creek expose antimony ore. These are sunk in chlorite schist at a limestone and schist contact. The limestone is bleached but not noticeably silicified. Details of the occurrence of the ore are obscured by wash in the trench. In one cut the mineralized rock is exposed for about 6 feet. The part seen is 2 feet thick; the base is

concealed, being overlain by gravel. The bottom of the pit is about at the limestone contact. In the ore on the dump stibnite is associated with quartz-calcite gangue. The relations are not clear, owing to the decomposed nature of the material, but the occurrence is probably one of stibnite in quartz, which lies in the limestone at a schist contact. Some stibnite also occurs as veinlets cutting schist.

A dozen or more pits have been dug S. 70° E. of the Cold Creek locality and on the west slope of the ridge between Steep and Manila creeks. No ledge is exposed. The country rock is chlorite schist. Some ore on the dumps would seem to indicate a vein trending about N. 45° E. and possibly 2 feet wide. The ore consists of stibnite and quartz and is similar to the other antimony ore of the locality.

The Christophosen antimony property is at the head of Waterfall Creek, about 5 miles west of the Sliscovich mine. (See fig. 19.) The lode is in a schist country rock. Development work consists of two tunnels and several open cuts. The upper tunnel, now caved and inaccessible, is said to be 105 feet long; the lower tunnel is 270 feet long and driven N. 25° W. According to Mertie,[62]

> The tunnels are said to intersect a stockwork of iron-stained schist and quartz in which the stibnite occurs as lenticular masses. None of the antimony stringers are over 12 inches in thickness.
>
> In the open cuts it is apparent that a shear zone striking about N. 20° E. runs through the property. The attitude of the faults is about vertical. This zone is about 100 feet thick and is heavily iron-stained and mineralized by pyrite, pyrrhotite, stibnite, and gold.

Little is exposed in the one tunnel which is accessible. About 60 feet from the portal a quartz vein, apparently a lens, is intersected which strikes N. 50° E. and dips 80° S. It is followed for 12 feet along its strike and apparently stoped. No evidence of mineralization is seen. At 70 feet from the entry a 3-foot quartz vein strikes N. 70° W. and dips north. The tunnel is driven in graphitic schist and exposes little quartz, other than that mentioned. On the dump quartz of the later-vein type contains considerable pyrite.

A 2-foot vein of quartz containing a little stibnite is exposed by the open cuts. It strikes N. 60° E. and dips north but can be traced for only a short distance. Quartz containing some stibnite occurs on the dumps of several open cuts. The antimony mineral, here as elsewhere, is later than the quartz occurring as veins through it. Concentrations of well-crystallized stibnite show included and evidently contemporaneous crystals of clear quartz, some of which have good terminations. The mineralized schist of the shear zone is exposed in several open cuts. The rock is a graphitic quartz schist containing a little sericite. It is highly iron-stained. Very little

[62] Mertie, J. B., jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 430, 1916.

quartz-vein material occurs through the mineralized shear zone. According to Mertie,[63]

> About 2½ tons of high-grade stibnite has been mined at this property and sold. The stibnite assays over 58 per cent antimony and carries also some gold and silver. Assays of the crushed schist and quartz in the shear zone also show a little gold.

ZINC-LEAD DEPOSIT ON STEEP CREEK.

The Nelson zinc-lead prospect is on the south slope of Mount Distin, near the headwaters of Steep Creek, a tributary of Goldbottom Creek (fig. 17). The developments consist of a 40-foot tunnel, a 30-foot open cut, and several pits. At the time of visit the tunnel was partly filled with water and inaccessible.

The country rock is limestone, with which is interbedded quartz-mica schist. Along a limestone and schist contact the limestone is bleached for a width of 30 feet. It strikes N. 15° W. and dips 18° W. Galena, sphalerite, and pyrite occur in the bleached limestone. At the mouth of the tunnel several stringers of sulphide occur parallel to the bedding of the limestone. The best exposure of the mineralized zone was seen in the open cut, where it is 6 feet wide. Almost every foot of face exposed, both laterally and vertically, shows sulphide, but the occurrence is very irregular and discontinuous. Veinlets of sulphide in the limestone parallel to its bedding constitute the usual mode of occurrence. One 2-inch veinlet of rather pure galena cuts the bedding and dips west at an angle of 35°. It is accompanied by gritty gouge, so badly decomposed that the relation of the sulphide to the gangue is not determinable. Viewed in the large the face of ore has a parallel structure, due to the arrangement of the veinlets. In detail the parallel zones are made up of smaller veinlets branching in all directions. The limestone here is not silicified. The sulphides occur as veinlets and replacement deposits in the limestone. Sphalerite is a common accessory mineral of the galena ores of Seward Peninsula but rarely occurs as the dominating sulphide. Mertie[64] has described such an occurrence in the headwater region of Penny River (fig. 19), as follows:

> A zinc prospect consisting of two claims owned by G. Christophosen is on the ridge between Penny River and the head of Oregon Creek, at an elevation of 1,600 feet. The prospect lies N. 64° E. from the mouth of Nugget Creek.
>
> The ore occurs in a small saddle on the ridge, in a narrow band of limestone country rock. A short distance away, on both sides of the saddle, the country rock is schist, and this rapid alternation of limestone and schist is a characteristic geologic feature in this vicinity. The strike of the country rock is N. 30° E. and the dip about 30° SW. There appears to be no well-defined vein but instead an iron-stained zone of mineralization, which trends approximately S. 8° E. The lode was located originally by float in the valley of Penny River. Development work consists mainly of a caved shallow shaft.

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[63] Mertie, J. B., jr., op. cit., p. 439.
[64] Idem, p. 447.

The ore is sphalerite, with a little pyrite, in a quartz gangue. Two kinds of quartz are present—the white, opaque variety and the clear, vitreous quartz. The latter appears to be either contemporaneous with the ore deposition or at least closely connected with it genetically. The ore is said to carry also some gold.

NOME REGION.

The richest placers developed in Seward Peninsula are those within a few miles of Nome, notably on Anvil, Dexter, and Glacier creeks. Gold placers have also been found at several localities in a belt some 15 miles wide and extending inland for some 20 miles. It is to be expected that where the richest placers have been found the greatest concentration of gold in bedrock would also occur. In spite of this apparently favorable condition and a large amount of prospecting, no commercial lode deposits have yet been developed in this region. It should be remembered, however, that mining costs, owing chiefly to the high price of fuel, mine timber, supplies, and transportation, are very high. A lode whose gold content was so low as to prohibit profitable exploitation under these conditions of high cost might be of commercial value if such conditions could be changed. Most of the prospecting has been done in search of gold, and both vein and shear-zone deposits have been explored. A number of deposits of antimony (stibnite) and several of tungsten (scheelite) have also received some attention.

The nature of the antimony mineralization has been described on page 225 and need not be mentioned further. Tungsten has been found in bedrock at Sophie Gulch, on Twin Mountain Creek,[65] in lodes on the north side of Glacier Creek, and on the divide between Glacier and Anvil creeks. In the tin deposits of the York district wolframite is associated with cassiterite. In the deposit cited above the tungsten mineral is scheelite. At Sophie Gulch it occurs as a contemporaneous constituent of the quartz-calcite veins and accompanying sulphides which have impregnated the schist adjacent to the veins. At Good Luck Gulch it is recognized microscopically, associated with pyrite, arsenopyrite, and quartz, replacing limestone. As it seems to be contemporaneous with both the later quartz veins and the arsenopyrite, more than one age of tungsten mineralization is certain. Scheelite is fairly common in the placers. It is known at Bluff and in the Council, Solomon, and Fairhaven districts and is probably widely distributed, perhaps as a minor constituent of the later quartz veins.

Quartz veins are very common in the Nome region. They occur as stringers and as massive veins as much as several feet in width. Free-milling gold is known to be present in veins as narrow as a quarter of an inch, but the gold content of all veins so far as known is uniformly

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[65] Mertie, J. B., jr., op. cit., p. 437.

low. The feldspar type of vein is best known in this district, and the conspicuous veins are usually of that type. No great enrichment of the country rock seems to be assignable to the quartz veins. It seems more probable that enrichment has been effected by the formation of mineralized shear zones and that the gold has been derived from arsenopyrite, which is the usual metallic mineral of those zones. Two types of shear zone in which sulphides are abundant are known. In one the ore occurs in the schist; in the other it occurs along walls of the later quartz veins.

The relation of arsenopyrite to the later quartz veins is similar to that of stibnite. After the deposition of the veins movement reopened the fissures and shattered the veins, and solutions bearing arsenopyrite, gold, a little pyrite, and very little quartz were introduced along the reopened fissures, filled fractures in the veins, and impregnated the schist wall. Unaltered sulphides in these deposits are rarely exposed, and details of the associations can not be seen. The deposits appear at the surface as zones of decomposed schist, stained red by iron oxide. The intense mineralization as shown by the decomposition extended for only a few feet from the vein wall and diminished rapidly with increasing distance from the vein. Where the fresh sulphide can be seen it is chiefly arsenopyrite. The decomposed schist pans gold. Polished and thin sections have not shown free gold to be included in or associated with the sulphides, and the gold mineralization may in part be independent of the sulphides. Mertie [66] cites a mill run made on one of these deposits in which the sulphides are said to have assayed $48 to $65 a ton in gold.

The mineralization of the shear zone in schist is comparable to that of the schist adjacent to the later veins, which has just been described. Sulphides, chiefly arsenopyrite, impregnate the schist. Stringers of quartz cut the schist, usually not in great numbers, but at Sophie Gulch and on Glacier Creek zones of this type are exposed in which the veinlets form regular stockworks. The limits of the zones are not well defined, the sulphide mineralization having gradually diminished with increasing distance from the main surfaces of shear. The weathered outcrops are stained with iron oxide. According to report, the schists show a gold content on assay, and gold can be panned from the decomposed materials.

Many lode claims have been staked in the Nome region during the last 20 years, and on some of these claims considerable underground exploration has been done. Though a little gold ore has been mined and milled from some of these prospects, and a few tons of antimony has been produced, no commercial ore bodies have been blocked out. For the sake of elucidating the principles governing the distri-

[66] Mertie, J. B., jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 432, 1916.

bution and mode of occurrence of gold in the bedrock, the principal prospects will be described. At the time of the writer's visit to this field in 1920 many of the old workings were caved and inaccessible. Fortunately, some record of the lodes is available, through the reports of Mertie [67] and Chapin,[68] who examined the region in 1913 and 1914. In the following descriptions extensive use will be made of these reports. The locations of the prospects here to be described, which lie close to Nome, are given on the accompanying maps (figs. 18 and 19).

Attempt to find a gold-bearing calcite lode is shown by some openings made by M. Charles at the head of Cooper Gulch, about half a mile east of Anvil Mountain. Here there are some small

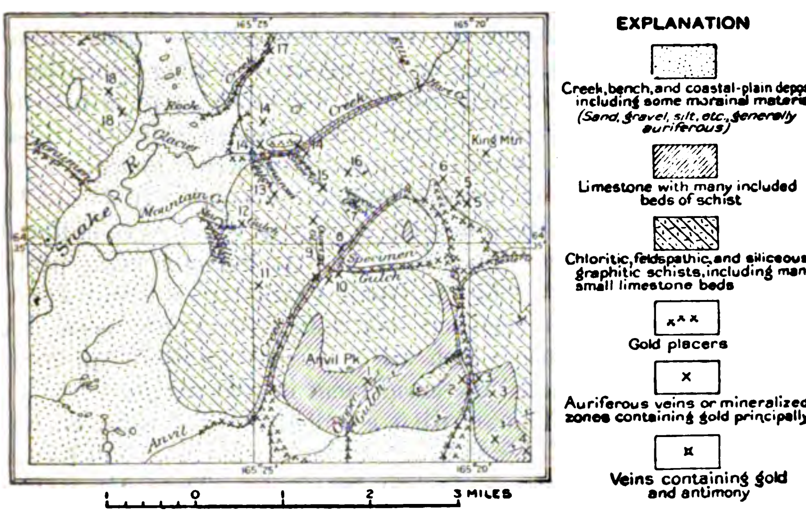

FIGURE 18.—Geologic sketch map of Anvil Creek and vicinity, 4 miles north of Nome.

reticulated veins of calcite which strike N. 30° E. Nothing encouraging the hope of finding a valuable lode was seen at this locality. The calcite veins and stringers carry some quartz and are iron-stained, showing the presence of a sulphide.

It is important to note the relation between the arsenopyrite deposits and some of the more productive placers of the peninsula as observed in the lodes at Bluff, at Koyana Creek, and on West Creek in the Solomon region (pp. 186, 198). The arsenopyrite-bearing rock is perhaps the most conspicuous type of mineralized rock in the Nome region, where it is known to occur on Goldbottom Creek, Good Luck Gulch, Boulder Creek, Gold Hill, Rock Creek, Sophie Gulch, Snow Gulch, Glacier Creek, Mountain Creek, New

[67] Mertie, J. B., Jr., Lode and placer mining on Seward Peninsula: U. S. Geol. Survey Bull. 662, pp. 425-440, 1917.

[68] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, pp. 397-407, 1914.

Years Gulch, and Anvil Creek and is suspected of being the source of the iron-stained schist of Dexter and Dry creeks. The known distribution of arsenopyrite in the Nome region as the principal sulphide mineral of the later quartz veins and of the shear zones suggests that it may be the same mineralization which has locally enriched the bedrock in this area and from which much of the gold of the rich placers has been derived. For many years prospectors have postulated a mother lode that supplied the gold for the rich placers of the Snake River drainage basin and the beach deposits. It is improbable that any one continuous lode exists. Relative enrichments such as are cited here would be sufficient to effect a tremendous concentration in the stream gravels if such enrichments were sufficiently numerous. The exposure of deposits of the shear-zone type in a country where the rock is concealed by moss, talus, and gravels is purely fortuitous or the result of mining operations. It is not improbable that such deposits are much more numerous than can be demonstrated. Shear zones comparable to those exposed in the Nome region are not known to the writer to occur elsewhere in the peninsula, but they are probably present. It would be natural to expect to find them developed in areas which have suffered the greatest deformation. The Nome and the Solomon areas probably fill this requirement. In the Ophir Creek region shear zones of this type were not recognized, nor was arsenopyrite seen. A different set of conditions, which are discussed elsewhere (p. 207), are believed to have effected the enrichment in that region.

Some work has been done on what is called the Rex lode, on the west slope of the Dry Creek valley. At an elevation of 550 feet a tunnel is driven 25 feet along a fault in limestone. The fault strikes N. 18° W. and dips 65° N., and the limestone strikes N. 40° E. and dips 10° N. A slightly iron-stained calcite vein, 1 foot or less in width, lies along the fault. The owner claims an assay of $3 to $5 in gold to the ton on this material. Another 25-foot tunnel 50 feet lower exposes the same vein. About 200 feet south of this second tunnel three tunnels have been driven on different veins and are now caved. One was 180 feet long. At an elevation of 480 feet a tunnel is now being driven N. 70° W. along an 8-inch vein of calcite. Here only calcite has been seen, and no quartz or sulphide minerals were observed.

A number of claims are staked on the Red lode, along the valley of Dry Creek, between elevations of 400 and 500 feet. East of the road just below East Gulch a pit exposes iron-stained schist similar to that observed on Dexter Creek. Both limestone and schist occur on the dump, and the hematitic material is probably related to the contact. A shaft 40 feet above the pit just mentioned is now caved. Limestone and quartz-chlorite schist but practically no quartz occur

on the dump. On the east side of Dry Creek, at an elevation of 500 feet, a 25-foot tunnel, now caved, and a 30-foot trench 50 feet above it have been opened on a fault zone in limestone. The fault zone strikes N. 40° W. and can be traced on the hillside. The limestone along the fault is brecciated and stained by hematite and limonite, which are accompanied by considerable calcite. No sulphides were seen. The oxide mineralization here probably resulted from ground waters circulating along this shattered zone and is illustrative of what may be the conditions giving rise to the iron ores of the Cub Bear mine on Cripple River.

An open cut at an elevation of about 770 feet on the east side of Dry Creek exposes iron-stained limestone. The cut is now caved, but some greenstone containing pyrite is on the dump. The sulphide content of this rock may be the source of the iron stain in the limestone at this locality.

At the head of Newton Gulch A. Homberger has made a dozen or more openings in limestone and schist. Veinlets of quartz in the schist and a little pyrite form the only evidence of mineralization seen. No defined lode has been followed, but an average value of $5 in gold to the ton is claimed by Mr. Homberger as the result of composite sampling.

Arthur Hines and Charles McLaughlin have located five claims covering most of King Mountain and five claims on the north slope of Dexter Creek, between Deer and Grouse gulches. On Dexter Creek six shafts, five 20 feet and one 56 feet deep, were sunk but are now caved. They were sunk in limestone and decomposed, highly iron-stained schist. The country rock here is alternating schist and limestone. The schist where exposed is decomposed almost to soil and stained yellow. Little quartz is seen, and the decomposed material is said not to pan a color, but to assay $3 to $24 a ton in gold. The owners also claim that it contains platinum. Platinum in rock of this type would be entirely exceptional, and its presence or absence should be determined by a competent chemist.

South of these claims, at the mouth of Grouse Gulch, there is an old tunnel at creek level, said to have been 400 feet long and to have cut decomposed schist that showed an average of $11.80 a ton in gold for 150 assays. This schist is about half calcite and half quartz, with a very little sericite.

The bedrock of Dexter Creek is alternating limestone and schist. Very little quartz is seen, but the thin schist zones are highly mineralized and much decomposed. On Grass Gulch and Left Fork the rock is chiefly limestone with a little interbedded schist and almost no quartz. The limestone is bleached white at certain horizons, chiefly at schist contacts. Miners working here say that the richest placer ground is found on the bleached limestone.

Bursick & Kern have made 8 or 10 openings at the base of King Mountain on the south and southwest sides. All are in schist and expose very little quartz. No evidence of mineralization was observed. A 20-foot tunnel in schist exposes a few inches of quartz but no trace of mineralization. At an elevation of 640 feet Bursick & Kern have a cut 30 by 50 feet in white limestone. The adjacent schist is well mineralized. The limestone resembles the bleached limestone that accompanies the mineralized rock elsewhere. The bed is 4 feet thick but is neither silicified nor mineralized. On Nekula Gulch, a quarter of a mile to the southwest, is the Caribou Bill claim, one of the richest placers mined in the district.[69]

New Years Gulch, a tributary to Anvil Creek, is cut through a zone of mineralized schist and quartz-feldspar veins similar to the zones exposed on Glacier and Rock creeks. The zone is 25 feet wide and strikes N. 40° W. (?). The iron-stained schist is said to pan gold. The vein material is reported to carry arsenopyrite and pyrite, but none was seen by the writer. An assay made for the Survey on this oxidized schist did not show any gold.

At the Hendrickson prospect, on the north side of Anvil Creek between New Years and Specimen gulches, a 150-foot adit exposes a little quartz, limestone, and schist. The limestone is highly mineralized. Pyrite and arsenopyrite occur abundantly in small crystals in a slightly schistose type of limestone, and pyrite occurs also in a nonschistose phase. The quartz shows some arsenopyrite mineralization. According to Mertie,[70] the adit is reported to crosscut a belt of mineralized country rock for 120 feet, and within this belt lies a rich zone 15 feet wide, which assayed $11 to $12 a ton in gold. A shaft on the opposite side of the creek is filled with water.

On the east bank of Anvil Creek just below New Years Gulch hydraulic work exposes much jointed schist that is well mineralized and on weathering is discolored. In some places the discoloration is more intense than in others and might well represent higher concentration of sulphides, of which New Years Gulch is an extreme example. Quartz veinlets occur throughout the schist.

Some of the gold from the hydraulic bench on Anvil Creek just above Specimen Gulch is attached to quartz, some is clean, and one nugget showed only hematite in the crevices. All the nuggets are angular and probably local. The attached material suggests that the gold may be derived in part from the quartz stringers and in part from the sulphides.

On the north bank of Anvil Creek, opposite the mouth of Specimen Gulch, a tunnel 70 feet long has been driven in graphitic schist. The

[69] Collier, A. J., Gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 200, 1908.

[70] Mertie, J. B., jr., op. cit., p. 431.

opening was made by J. C. Widstedt in 1899, and several tons of antimony was mined. The stibnite occurred in kidneys in the schist but not in large quantities. The schist in the vicinity of the stibnite kidneys is well mineralized by pyrite and arsenopyrite. Samples of the ore show coarsely crystalline stibnite and a little pyrite. It is said to have assayed $72 a ton in gold, $28 in silver, and some copper. Little can be seen in the tunnel, because of the sediment covering the walls.

On the west bank of Quartz Gulch, about halfway up the gulch, a shaft was sunk by Mr. Widstedt on an antimony-bearing quartz vein. The shaft is now full of water. The material on the dump consists of quartz, schist, and stibnite. The stibnite is finely crystalline and is associated with pyrite and a little arsenopyrite. In the quartz rock stibnite occurs in veinlets. Where stibnite predominates the relations of the quartz are not clear.

On the hillside northwest of this locality is another shaft now caved, out of which antimony is said to have been mined; only schist shows on the dump. On the east side of Quartz Gulch a small open cut exposes several parallel quartz stringers in iron-stained schist. The decomposed zone is 12 feet wide. Finely crystalline stibnite occurs in tiny veinlets in the quartz.

On the west side of Anvil Creek opposite the mouth of Specimen Gulch an open cut exposes a shear zone in schist. The schist is about half calcite and half quartz, with much graphite and a little muscovite. It is badly crumpled and iron stained. Numerous indistinct quartz veinlets cut the schist. Pyrite was the only fresh sulphide seen. Beginning 100 feet south of this exposure and continuing for several hundred feet a series of these sheared and iron-stained zones in schist are exposed by a cut made in building a road along the side hill. The occurrence is similar to that of the Boulder lode and other sheared zones which are known to pan gold and is probably representative of a type of sulphide mineralization common in the Nome district but not generally exposed. On the west side of Anvil Creek below Quartz Gulch several tunnels have been driven but are now caved and inaccessible. No ore was seen on the dumps. One of these tunnels was evidently driven on a limestone and schist contact. Quartz-calcite veinlets occur in both limestone and schist, and sulphides are prominent in both. At the mouth of Quartz Gulch on the Scotia claim a 10-foot tunnel exposes an 8-inch quartz-calcite vein, cutting schist. Both schist and quartz contain pyrite and arsenopyrite.

On the east bank of Anvil Creek a quarter of a mile below Specimen Gulch two shafts have been sunk by Charles Olsen on antimony-gold-quartz veins. One, 54 feet deep, is now caved; the other, 100 feet

deep, is full of water. The 54-foot shaft, according to Mr. Olsen, was sunk on a 4-foot vein of quartz that strikes a little west of north and carried only a little gold. At a depth of 49 feet stibnite was encountered which continued to 54 feet, where the shaft was abandoned. The stibnite portion of the vein was more than 5 feet wide. The 100-foot shaft is 100 feet west of the 54-foot shaft. It encountered stibnite at 60 feet, which continued on the hanging wall to 100 feet, and at that depth the shaft was abandoned because of water. These veins dipped west and had 10 feet of talc schist on the hanging wall. The ore occurring on the dump is very finely crystalline stibnite with some pyrite and quartz through it. It is said to have assayed $21 to the ton in gold, $2.05 in silver, and some copper.

On the ridge between Anvil Creek and Snake River, southwest of Quartz Gulch, at an elevation of 650 feet, a big ledge of white, opaque (bull) quartz has been exposed by Peterson & Lamoreaux in an open cut and short tunnel. This body of quartz is 8 feet or more thick, strikes S. 45° W., and dips about 45° NW. It is heavily iron stained. The vein is not clean cut but shows stringers going off into the black schist country rock. Strongly developed fractures striking N. 35° W. are present in the quartz, as well as other irregular fractures and faults. This quartz has the appearance of having suffered considerable metamorphism and is probably an old quartz vein formed prior to the gold mineralization of the region. It is reported that galena was found disseminated in some of this quartz. A near-by shaft, about 40 feet deep, is filled with water.[71]

The Eureka and Borasco claims, usually known as the Jorgensen property, lie on Mary Gulch, a tributary of Mountain Creek. Here several openings have been made on quartz veins in mineralized mica schist and marmarized limestone. Oligoclase feldspar is prominent in some of the vein rock. Pyrite, arsenopyrite, and galena occur in veins cutting the quartz, and Mertie [72] reports scheelite from the same locality. The galena occurs in veinlets in the quartz but was not seen in association with the other sulphide and may represent a different period of mineralization. Scheelite may belong to either the quartz or the sulphide period of mineralization. The schist is highly mineralized with arsenopyrite and pyrite. The sulphides are concentrated along the vein, and in the weathered outcrop the schist adjacent to the vein is altered to hematitic material. This intensely iron-stained zone may extend a foot or more from the vein. It is reported that gold can be panned from this rock and that the vein carries gold. Shearing along the vein is apparent. The order of mineralization would seem to be as follows: Quartz, probably carrying a little gold and scheelite, was introduced first. Later movement, in part at least along the vein, reopened the fissure and shattered the quartz. Contemporaneous with or later than this movement sulphides carrying gold filled fissures in the vein and impregnated the

[71] Mertie, J. B., jr., op. cit., p. 432.
[72] Idem, p. 435.

schist wall rock. The gold content of this and of most of the quartz-feldspar veins of the area about which anything could be learned seems to occur chiefly in the sulphides.

About 200 feet above the forks of the creek a cut exposes quartz in limestone. The habit of the quartz occurring in the two formations is well contrasted. In the schist the veins are extremely irregular in the strike and dip and are subject to rapid pinching and swelling. In the limestone the veins are, as a rule, more clean cut but in places subject to irregularities. At this locality the quartz has followed in general the bedding of the limestone, but in two places it cuts the bedding and fills irregular openings. The quartz in the limestone shows some galena but seems to be less well mineralized than that exposed in the schist.

The Golden Eagle and Gold Bug claims of the West group are near the head of Bonanza Gulch, half a mile south of Glacier Creek, near the top of the divide between Anvil Creek and Nome River. Here a 120-foot adit has been driven on a vein of the quartz-feldspar type. It shows a little pyrite and arsenopyrite. The country rock is quartz-mica-chlorite schist and where exposed, adjacent to the vein, is intensely iron stained. This soft hematitic material is said to pan gold. The width of the mineralized schist zone is not determinable. It strikes about N. 70° E. The face of the drift exposes a nearly vertical 8-inch vein in a zone of soft, highly altered schist. The exposures do not show the structural features.

About 200 yards north of the west end of Hot Air bench, between Glacier and Rock creeks, a trench exposes a quartz-feldspar vein in which sulphides are abundant. Arsenopyrite and pyrite occur in veinlets that cut the feldspar and quartz. There is a noticeable association of the sulphides with the feldspar of the vein. The relations of the vein to the bedrock could not be determined.

On the south side of Glacier Creek above Snow Gulch several short tunnels are driven on quartz-feldspar veins. In one tunnel 100 yards above the gulch the vein exposed is 1½ feet thick. Arsenopyrite and pyrite occur in veinlets through the quartz and feldspar of the vein.

On the north bank of Glacier Creek, opposite the mouth of Snow Gulch, a tunnel driven 20 feet in schist exposes a 1-foot quartz-feldspar vein. The country rock, quartz-chlorite schist, strikes N. 60° W. and dips 20° N. The vein strikes east and dips south at an angle ranging from practically nothing to 45°. The schist is highly folded and irregular. The vein pinches and swells from 3 inches to 1 foot within the 6 feet of length exposed. An 8-inch lens of quartz is exposed above the vein but extends for only 2 feet. A 1-inch stringer dips north and merges with the vein. The quartz

shows little or no mineralization, but the schist adjacent to it is well mineralized with arsenopyrite and pyrite.

A zone of mineralized schist impregnated by quartz is exposed in a small gully on the south bank of Glacier Creek just above the mouth of Snow Gulch. The occurrence is similar to that of Sophie Gulch. The zone appears to strike N. 30° E. Its width is not determinable. The schist has been literally shattered, and the fractures strike and dip in all directions. The schist included between veinlets is commonly curled and contorted along what probably are the surfaces of greatest movement. The veins are of the quartz-feldspar variety and from 1 to 3 inches in width. They are extremely irregular, pinching and swelling, forming lenses and blowouts, and ending as abruptly as they begin. They are all contemporaneous, branching and anastomosing and conforming with the fractures in the schist. The fissures filled are clean cut, and the vein walls are well defined. Between the veins and especially adjacent to them the schist is intensely iron stained. Only extremely decomposed material can be seen, so that the nature of the sulphide mineralization by which it was formed is not determinable. It is probably another exposure of that type of rock containing disseminated sulphides, which in places is known to carry gold and which may be very common, as the softness of the material would permit its exposure only under exceptional conditions. Both moss and talus would effectually conceal it.

The quartz veins are probably later than any considerable movement along the intruded zone, as no offsetting was observed. The sulphide mineralization of the schist was, at least in part, later than the introduction of the quartz, as arsenopyrite, the most abundant sulphide of these zones, occurs as veins in the quartz. How far the sulphide mineralization may have extended from the vein has not been determined, but to judge from the intensity of the decomposition colors it was largely concentrated within a few inches of the vein. This criterion is fairly reliable, as water circulation is not confined to the vein fissures, and the wall rock is cut in great detail by incipient fractures and is decidedly porous rather than dense, even in its most unaltered parts.

The localization of the schist mineralization largely along the fissures filled by quartz indicates the same control for the sulphide mineralizing solution as for the quartz. The old avenues of entrance were open, whether due to incomplete filling of the fissures by quartz or to later shattering that affected the vein walls. Free gold can be panned from many of these zones of decomposed schist. The quartz-feldspar veins are known to carry gold. Whether the gold is the product of a separate mineralization or related to the sulphide

mineralization is not definitely known. According to Chapin,[73] the sulphides at the New Era tunnel do not pan free gold. The decomposed schists carrying the same sulphides in many places pan gold. At Bluff (p. 186) the ore is similar to that which is in part free milling and in part base.

At creek level, just west of Hot Air bench, on the north bank of Glacier Creek, two 30-foot open cuts and a 15-foot adit expose a vein of the quartz-feldspar type. The country rock is chlorite schist, which strikes east and dips 40° S. The vein is 8 inches thick and conforms in general with the irregular strike and dip of the schist. A fault in the schist at the tunnel face strikes N. 70° W. and dips 45° N. The vein has been terminated by the fault gouge on the west side of the drift and cuts the fault surface on the east side of the drift. It is almost certain from observations made on this vein that it is later than any period of serious deformation of the schist. It is shattered but not displaced. No sulphide mineralization of the vein was observed.

The Hot Air bench, on the north bank of Glacier Creek, was a large producer of placer gold. The bedrock is schist, and quartz is not plentiful. The schist is mineralized, but the shear zones observed in the bedrock of Rock and Anvil creeks are not seen here. It hardly seems possible that this gold could have been of local derivation. Microscopically the schist proves to be a quartz-albite variety in which chlorite is the most abundant micaceous mineral and muscovite is prominent. Sillimanite and titanite occur as accessories, and arsenopyrite seems to be the sulphide.

The New Era tunnel, on the west side of Snow Gulch, near its head, is now caved and inaccessible. The country rock of Snow Gulch is a succession of limestones and schists, and the tunnel is driven along one of the schist zones. Quartz, limestone, and calcareous schist on the dump are not representative of the mineralization, which is described by Chapin[74] as follows:

> The lode, as judged by specimens from the dump, is composed of stringers of quartz with much included schist, both quartz and schist containing considerable pyrite and arsenopyrite. The arsenopyrite occurs as small irregular bunches and as isolated crystals in both vein matter and schist and appears to be contemporaneous with the quartz. Some of the pyrite may perhaps have the same relation, but most of it is of later origin than the arsenopyrite and fills fractures which penetrate that mineral. A small amount of albite occurs with the quartz.
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> No visible gold could be detected in any of the samples taken from this tunnel, nor can free gold be obtained on crushing the ore. The gold is contained in the sulphide and extends into the wall rock for a considerable distance.

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[73] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, p. 400, 1914.
[74] Idem, p. 400.

West of Snow Gulch, at an elevation of about 450 feet, a trench 50 feet long and 12 feet deep at the face exposes a quartz-calcite vein in limestone. A 12-foot shaft and a 20-foot shaft on the strike of the trench expose the ledge for 100 feet to the southwest. The vein is 2 or 3 feet thick, strikes N. 20° E., and dips 15°–30° W. It conforms in general with the bedding of the limestone. A very little sulphide was seen in both limestone and quartz. Continuing along the direction of these openings, in a line N. 25° E., twenty or more pits have been sunk in quartz-muscovite schist. A little quartz, about equivalent to the quartz occurring in the schist anywhere, is on the dump at each opening, but no ledge is exposed. The pits extend for half a mile or more.

On one of the Big Four claims, on the east side of Snow Gulch above the Miocene Ditch tunnel, a 20-foot shaft and several open cuts have exposed a quartz vein system in limestone. The veins are of the quartz-calcite type, are of open texture, and contain a little sulphide. Free gold was observed in one vein at the contact of the vein and the limestone. In the shaft the veins occur dominantly with the bedding of the limestone but are also transverse to it. They appear to be fairly continuous and not to exceed a few inches in width. The limestone is underlain by schist, and several openings are made in the contact. The schist is highly mineralized.

Where the Government road crosses Rock Creek there is an outcrop of limestone which shows considerable sulphide mineralization. The mineralized limestone is dark blue to black, much contorted, slickensided on some surfaces, and cut by small veinlets of quartz. The microscope shows that it is partly replaced by quartz, being about half quartz and half calcite. The only sulphide observed is pyrite.

The folding in the limestone and schist is exposed on the creek bank. Along the crest of an anticline, where the limestone is in contact with schist, both rocks are unusually well mineralized. The schist resembles that of the Boulder and California lodes, being highly iron stained. No well-defined quartz veinlets occur in the mineralized rock, and apparently the mineralizing solutions contained little or no silica. Here, as at Good Luck Gulch, however, the sulphide accompanies the quartz in replacing limestone. The crest of a fold is here seen to have afforded an opening favorable to the introduction of the mineralizing solutions.

On the north bank of Rock Creek, 200 yards northwest of the road crossing, a caved 10-foot shaft exposes a 2-foot vein of the quartz-feldspar type. The vein strikes N. 30° W. and dips 90°. Several openings south of the creek are along the strike of this vein and possibly on it.

On the south bank of Rock Creek, just below Sophie Gulch, two tunnels, a shaft, and an open cut have been made on a quartz-feldspar

vein. The tunnels are driven S. 75° E. and S. 25° E. about 100 feet apart, and the shaft is probably sunk at their intersection. Both tunnels are caved, and the shaft is filled with water. The vein strikes N. 65° E. and dips 50° S. It is partly exposed by a cut and appears to be 3 or 4 feet thick. The feldspar of the vein is albite. It also contains a little pyrite, arsenopyrite, and ilmenite. The country rock is quartz-chlorite schist, which is iron stained at the surface. Material on the dump of the shaft contains fresh sulphides, the ilmenite occurring on fractured surfaces in the quartz.

This is the property referred to by Mertie as the Stipec and Kotovic property. He says: [75]

> The tunnel cuts a 12-foot vein of white opaque quartz which is greatly shattered and iron stained. A mill run on this material has shown it to contain 250 pounds of concentrates to the ton of rock milled and $6.25 a ton in free gold. The concentrates, which are chiefly arsenopyrite and pyrite, are said to assay from $48 to $65 a ton in gold. It is said by the owners that the schist in the mineralized zone carries more gold than the mineralized quartz.

In a hydraulic cut (Reinisch pit) on the north bench of Rock Creek opposite Sophie Gulch free gold was observed in a quartz stringer cutting black schist made up essentially of quartz, muscovite, and carbon. The stringer consists of white, vitreous quartz, about half an inch wide, which abounds in openings. In places the fissure is clearly incompletely filled, well-terminated crystals projecting from one wall, while no quartz occurs on the wall opposite. The gold seems to occur on the crystalline quartz and to be later than the quartz, but the evidence is too meager to warrant a positive statement of this relation. The miners report that gold usually occurs between the quartz and the wall rock.

Mertie [76] has described the occurrence of scheelite on Sophie Gulch as follows:

> The property known as the Sophie lode, on Sophie Gulch, a tributary of Rock Creek, consists of one patented placer claim and two lode claims. Residually weathered tungsten ore was mined here by placer operations in 1916. * * * The results of microscopic work on this lode will be included in a later report.
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> The country rock at this place is an iron-stained, thin-cleaving, foliated mica schist. the cleavage of which, measured at one place in the pit, strikes north and dips 23° E, It shows also a vertical jointing trending N. 35° W. Many well-developed fissures are present, striking N. 45° E. and nearly vertical or dipping steeply to the northwest. These are filled with iron-stained shattered quartz. Such veins range in thickness from a fraction of an inch to a foot or more. There is great irregularity in these quartz stringers, most of them thickening in places and thinning in others; also stringers run out into the country rock. Iron-stained fault planes striking N. 18° W. and dipping 54° E. cut both the country rock and the quartz stringers, and along these there is little or no quartz but considerable iron-stained gouge material.

[75] Mertie, J. B., Jr., Lode and placer mining on Seward Peninsula, U. S. Geol. Survey Bull. 662, p. 433, 1917.

[76] Idem, p. 436.

The scheelite occurs for the most part along the sides of quartz stringers and disseminated in the mica schist. Locally the scheelite is present in the quartz. It is reported that gold occurs in the iron-stained schist outside of the zone of scheelite mineralization, but no gold is reported to have been found in the scheelite-bearing rock. Besides scheelite, however, arsenopyrite, pyrite, and galena are found in the form of later veinlets definitely cutting the quartz.

It is said by the owners that the belt of scheelite mineralization is about 50 feet wide and has so far been traced about 500 feet in each direction from the open cut. The trend of this zone appears to be that of the iron-stained quartz veins and stringers—that is, about N. 45° E. The northwest side of the lode is reported to carry more scheelite than the other side. Two shafts—one 32 feet deep, northeast of the open cut, and the other 28 feet deep, southwest of the cut—have been driven to ascertain the value of the ore along the lode. It is said that these shafts show a higher content of scheelite in depth than at the surface.

The writer can supplement the above description by his own observations. The veins are all contemporaneous, cut the schist in all directions, and form complex patterns on the walls of the cut. They are of the quartz-feldspar and quartz-calcite types, are badly shattered, and crumble under the pick. Adjacent to the quartz and extending several inches or a foot from the vein the schist is intensely iron-stained, having the appearance of hematite. Where the veins are close together the entire body of intervening schist may be so altered. Arsenopyrite, galena, and pyrite occur in veinlets through the quartz. Arsenopyrite is also seen in the wall rock of the vein and is probably the mineral from which the hematite is derived. The iron-stained and highly mineralized schist is said to carry gold. A specimen of scheelite-bearing quartz vein material from this locality showed the scheelite to be yellowish brown and the quartz clear and colorless. White calcite is a prominent constituent of the vein rock.

At the mouth of Sophie Gulch a tunnel has been driven on a quartz-feldspar vein in a zone of mineralized and highly iron-stained schist. The tunnel is caved and inaccessible. Vein material on the dump contains arsenopyrite.

Just east of the mouth of Sophie Gulch a hydraulic pit on the south side of Rock Creek exposes highly mineralized chlorite schist that strikes N. 40° E. and dips 20° E. The schist is cut by 23 quartz veins from 1 to 8 inches wide in an exposed width of 28 feet. The veins are roughly parallel and alined about with the strike of the schist. Arsenopyrite, galena, and stibnite were observed in the veins, which are of the open-textured quartz-feldspar type. The schist is mineralized, and hematite occurs along the vein walls. Concentrates from the sluice boxes at this pit are chiefly scheelite, quartz, and schist. Placer gold with very delicate structure and attached to quartz also occurs and is undoubtedly derived from a local bedrock source.

Half a mile above Sophie Gulch, on the south bank of Rock Creek, a tunnel is driven S. 55° E. in chlorite schist. The working is inaccessible. Ore on the dump is quartz-feldspar vein material contain-

ing arsenopyrite and pyrite. The schist adjacent to the quartz is impregnated with fresh sulphides and is in all probability the equivalent of the hematitic schist which is of common occurrence on Rock Creek and which pans gold in many localities. The arsenopyrite mineralization seems to have been later than the vein and probably followed the same fissure as the quartz.

Two openings have been made on quartz veins on Gold Hill, in the Snake River valley between Monument and Thompson creeks. At an elevation of about 150 feet, opposite the mouth of Rock Creek, an open cut exposes a vein of the quartz-feldspar type. No sulphides were observed in the quartz, but it is said to assay $3.50 to the ton in gold. The country rock is much contorted quartz-chlorite schist, which in the vicinity of the vein is highly iron-stained and is said to pan free gold. The vein is about 2 feet thick, strikes N. 25° W., and dips south. The attitude of the vein is conformable with the structure of the schist, being very irregular and changing from horizontal to vertical where exposed. Small quartz veinlets ramify through the decomposed schist in the vicinity of the vein. Near the top of the hill a trench exposes a similar vein in highly decomposed and iron-stained schist.

On the north bank of Albion Creek, tributary to Rock Creek, a shaft said to be 50 feet deep has been sunk on a quartz vein. The shaft is now partly filled with water. No vein is in sight, and only a little quartz and some slightly mineralized schist appear on the dump. The vein is said to have given assays of $120 a ton in gold but to have pinched out. No work has been done on the property for years. The country rock is chlorite schist. Quartz stringers are abundant in the schist at this locality.

Two openings have been made in schist and in vein quartz at the mouth of Good Luck Gulch, a tributary of Snake River from the east 3 miles north of Rock Creek. The southerly opening consists of a 40-foot trench trending N. 75° W. The banks of the trench are caved, and no rock is exposed in place. The schist is highly iron-stained and decomposed. Some quartz vein material occurs on the dump, and several sacks of ore apparently from this working are stacked on the river bank near by. The material is highly mineralized. Pyrite and arsenopyrite occur in a gangue of quartz and calcite, through which muscovite in small flakes is scattered in considerable amount. Arsenopyrite is the more abundant of the sulphides. A single small crystal of scheelite is seen in thin section. In hand specimen the rock is blue and calcareous. It is probably a replaced limestone, but there is no field evidence to verify this conclusion.

Several pits along the strike of the lode expose no rock in place. Material on the dump includes iron-stained schist and a little banded

quartz rock containing pyrite and similar in appearance to the copper ores of Copper Mountain (p. 217). The bedrock occurrence of this material can not be seen.

About 100 yards north of these pits a trench 30 feet long is driven N. 85° W. along the strike of a vein which dips 70° S. The vein is almost covered by débris. Where exposed it is 1 foot wide at the surface and 3 inches wide where it disappears in the trench floor. Material on the dump indicates that the vein may have had a thickness of 3 or 4 feet in one place. The vein is of the quartz-feldspar type and shows openings lined with quartz crystals. Pyrite and arsenopyrite occur through the quartz. The including rock is highly mineralized quartz-mica schist that strikes N. 75° W. and dips 25° N.

Many of the streams tributary to Nome River from the west between Alpha Creek on the south and Last Chance Creek on the north carry auriferous gravels, and these have locally yielded much placer gold. These creeks therefore apparently traverse a zone which is locally auriferous about 8 miles in length and 2 miles in maximum width. More accurate evidence of bedrock mineralization has been found at many localities in the form of auriferous zones and small quartz veins. Moffit [77] in 1906 noted the presence of mineralized bedrock in this zone as follows:

A large amount of highly mineralized quartz is present in schist exposures south of Good Luck Gulch. The quartz is much crushed and in general occurs as stringers, although at one place a mass 4 or 5 feet wide is exposed in a small outcrop. A prospect hole shows much rotten iron-stained quartz. The schist also is filled with iron oxide, in which some pyrite still remains. Panning shows the presence of gold.

Several quartz veins, the largest of which is about 5 inches thick, occur near the mouth of Boulder Creek. Assay values of $3 to $4 a ton in gold were obtained from samples taken here.

On Pioneer Gulch the best ground of the residual placers occurs just below a number of small quartz stringers cutting the schist bedrock. One of these stringers 3 inches thick showed considerable free gold. Similar occurrences are known in other parts of the region, but nowhere has the number or size of the mineralized veins been sufficiently great to constitute an ore body.

Moffit [78] noted the presence of scheelite and hematite pebbles associated with the placer gold of Bangor Creek, which contained fragments of scheelite weighing half a pound. The placers of Last Chance Creek, he states, carry scheelite, hematite, magnetite, and pyrite.

In 1907 Claus Rodine found a gold-bearing ledge on Twin Mountain Creek. Since then gold-bearing lodes have been found at a number of other localities in this belt. The general features of the bedrock geology are simple, for the belt is made up almost entirely of schist,

[77] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, p. 131, 1913.
[78] Idem, p. 87.

which here and there includes some beds or lenses of limestone. There are, however, considerable local variations in the geology, for the schist includes feldspathic, micaceous, chloritic, and graphitic varieties. The schists in general trend north and are closely folded and much faulted. The evidence in hand goes to show that the mineralized zones are in general parallel to the schist, though there are some local variations from this strike.

Alpha Creek, the most southerly of the streams in this belt, has produced considerable placer gold. This gold is but little worn and probably of local bedrock derivation. The creek is cut in gravel, and the country rock is exposed only where a small area has been cleaned in mining. The bedrock exposed is chiefly quartz-mica schist and is well mineralized. Many quartz stringers cut the schist. The quartz is of a clear vitreous granular variety containing some fresh and considerable decomposed sulphide. A. C. Stewart is said to have had $12 assays on some of these stringers, but a composite sample of the quartz veinlets assayed for the Survey did not show any gold content. A little limestone and a little quartz from a larger vein than any seen occurs in the wash, but the gravel consists largely of the local schist and quartz stringer material. This occurrence would appear to be assignable to local quartz veins in schist bedrock, but the veinlets that would logically seem to be the source gave negative returns when assayed. Either the gold is not uniformly disseminated through the quartz or it is concentrated in certain veins. It is quite probable that the gold may have come from the mineralized schist and not from quartz veins.

There has been more prospecting of lodes on Boulder Creek and its tributary Twin Mountain Creek than in any other part of this belt. Here a large group of claims was located in 1915 by W. L. Cochrane and Claus Rodine, of the Dakota-Alaska Mining Co. This and other groups extend from Alpha Creek on the south across Sledge and Boulder creeks and up Twin Mountain Creek nearly to its head. Another group of lode claims covers much of the valley of Boulder Creek.

A vein of quartz has been opened on the north slope of Sledge Creek about 1½ miles above its mouth (fig. 19). This vein, as shown in a cut about 20 feet long, is about 2 feet wide, strikes N. 40° E., and dips 70° E. It is made up of quartz and orthoclase feldspar. Some masses of feldspar measuring several inches were seen in the vein. The quartz is iron-stained, but no sulphides were observed in it.

Mertie[79] has described the lodes of Boulder Creek as follows:

A number of lode claims on Boulder Creek owned by W. L. Cochrane and Claus Rodine are being prospected. The Boulder lode, embracing several of these claims,

[79] Op. cit., pp. 427-429.

is on the southwest side of Boulder Creek at an elevation of about 250 feet. Development work on this lode up to November, 1916, consisted of a tunnel driven 92 feet into the hillside on the southwest side of the creek. The direction of the tunnel, 60° W., is about the same as that of the cleavage in the schistose rock. The rock through which the tunnel is being driven is a much altered schist, heavily impregnated by iron-bearing solutions and cut by numerous veins and lenses of white, opaque quartz and also by thin stringers of limonitic material.

It is apparent that the gold in the tunnel has a genetic relation to the iron minerals, but it is not believed by the writer that the white, opaque quartz had any direct connection with the gold mineralization, for the quartz shows the effects of shattering and iron impregnation in a measure comparable with the schist itself and therefore was present prior to the mineralization. The presence of the white, opaque quartz is believed to be merely fortuitous, though it may have had an indirect influence on the mineralization by assisting mechanically or chemically in the precipitation from the mineralizing solutions.

The only quartz seen by the writer other than the white, opaque quartz was a veinlet of clear granular quartz, about three-eighths of an inch thick, near the face of the tunnel. Evidently the mineralization took place with very little deposition of silica by the auriferous solutions.

About 50 pounds of stibnite was taken from an open cut at the surface a short distance west of the tunnel. Scheelite in well-developed crystal outline has also been found in the white quartz in the tunnel. It is rather likely that the scheelite represents another stage in this mineralization, or possibly an entirely different period of mineralization.

At the time of the writer's visit to this lode the tunnel had been driven 85 feet, and although there was much evidence of mineralization in the iron-stained schist sulphides in any notable amount had not been found. Subsequently, in further driving of the tunnel, sulphide ore was encountered in the lode material. Specimens of the last material taken from the tunnel were sent to the writer by Mr. Rodine and prove to contain both pyrite and arsenopyrite.

The Boulder lode is similar in many respects to the California quartz lode on Goldbottom Creek—that is, it is a lode of the disseminated type—a mineralized body lying probably in a zone of shearing. Mr. Rodine says that the trend of the lode, or, in other words, of this zone of disturbance, is about N. 3° E. If this is the correct direction of the lode, it would appear that the tunnel has crosscut about 76 feet of the mineralized zone, and in striking the sulphide ore the tunnel is probably entering the higher-grade ore.

Assays have been made about every 10 feet in this tunnel, and these, known in a general way to the writer, are considered favorable in so large a body of mineralized rock. If the assays are reliable, there is here evidently a good-sized body of low-grade ore. Yet the owners should do a great deal more prospecting on the lode, particularly drill-hole prospecting, to determine its width and extension before making preparations for a milling plant.

On the northeast side of Boulder Creek another tunnel 35 feet long has been driven on the Dakota lode, which embraces 13 claims. The country rock here is limestone, with a minimum of iron staining and practically no sulphides. Veins of white, opaque quartz and of calcite are present, but there seems to be little indication of any intense mineralization.

Bedrock is uncovered in a pit in the creek bed on claim No. 1 below Discovery, Boulder Creek. The country rock is an iron-stained schist, the cleavage of which strikes N. 60° W. and dips 30° SW. A fault zone trending N. 30° W. and dipping southwest cuts through the schist at this locality. A vein of the white quartz near by strikes N. 60° E. and dips steeply northwest. The fault zone is greatly iron stained

and cut by limonitic stringers. This material pans gold, and some very rich pieces of gold-bearing white quartz have been taken from this locality.

An open cut on the northeast side of Boulder Creek farther downstream has exposed a good-sized ledge of the white quartz. This is chiefly of interest on account of the presence of pyrite and pyrrhotite together in the quartz, the pyrrhotite being much less plentiful in the Nome district than pyrite or arsenopyrite.

When the writer examined this locality the mine workings were not accessible, but he was able to make more detailed observations on some of the bedrock geology than Mertie.

A 20-foot cut in the hillside near the mouth of Boulder Creek on the north bank exposes a quartz vein. The country rock is chlorite schist, striking N. 15° E. and dipping 15° E., which is highly contorted and shows considerable decomposed sulphide. The vein occurs as several stringers which in part cut across and in part conform with the schistosity. It swells to a foot in width and pinches to a few inches within a few feet. It is of the quartz-calcite type. No mineralization was observed.

On the north bank of Boulder Creek about 200 yards below the mouth of Twin Mountain Creek a 35-foot tunnel is driven in limestone. Several small stringers of quartz and calcite are intersected. Pyrite occurring in calcite is the only metallic mineral observed.

Near the mouth of Twin Mountain Creek and on the east bank two tunnels have been driven on veins of the quartz-calcite type. One is caved and inaccessible; the other, 40 feet long, is driven in chlorite schist and exposes a quartz-feldspar vein 15 feet from the portal. This vein swells from 1 inch to 1 foot in thickness and pinches to a stringer within 4 feet. Pyrite and a little arsenopyrite occur in veinlets through the quartz, and scheelite is said to be a constituent of the vein. The tunnel is driven S. 85° E. The schist strikes N. 5° E. and dips east. The vein in general conforms with the strike and dip of the schist.

The bedrock of Twin Mountain Creek is schist for several claims above the mouth. The gold it contains is hardly assignable to the influence of limestone, but rather to quartz veins, which are plentiful. Miners claim that the gold comes from an older and higher channel. The creek is incised in high terraces which merge with the terraces of Boulder Creek.

The Boulder lode is on the south side of Boulder Creek about a quarter of a mile above the mouth of Twin Mountain Creek. The workings consist of the tunnel described by Mertie and a shallow shaft. Both are now caved and inaccessible. The lode is evidently a shear zone in schist. The schist is highly stained with iron oxide, and some quartz occurs in stringers through it. To judge from the alinement of the workings and from traceable scars in the hills north of Boulder Creek valley, the strike of the lode is about north.

Limestone both underlies and overlies the schist zone of the lode, which is about 100 feet wide. The underlying limestone shows close folding both along its strike and along its dip, a feature which is well shown on the differentially weathered fracture surfaces of the beds. The stratigraphic position of the mineralized schist zone is shown by exposures along a ditch in the creek bank. West of the lode limestone immediately overlies it. The limestone strikes N. 10° E. and dips 20° W., thus conforming in general with the strike of the lode. Overlying this limestone, which is 50 feet or more thick, schist predominates in the section to the head of Boulder Creek. One considerable bed of limestone occurs about half a mile to the west, but it dips east and may be the same limestone which overlies the lode, duplicated by folding. To the east of the lode the series is predominantly limestone, with interbedded schist. The limestone occurs in thicknesses of 50 to 100 feet, and its structural relations are complex. East, west, and northeast dips are recorded within a few hundred feet. The included beds of schist are well mineralized.

Apparently the lode represents a zone of shearing in the schist at the contact of a zone which is predominantly limestone with a zone which is predominantly schist. The limestone near the lode is completely marmarized and shows intense deformation in detail and everywhere a complexity of structure. No doubt shearing occurred along all the schist zones in the limestone, for they are well mineralized, but the greatest adjustment occurred at the margin of the limestone mass, and this became the most favorable opening for later mineralizing solutions.

The lode rock is quartz-mica schist, in which chlorite and muscovite are abundant. Quartz is not present in any great amount. The material on the dump is of the later open-textured quartz-calcite vein type. Sulphides are abundant in the schist and occur also in the quartz and limestone and in calcite veins in the limestone. Pyrite is most common. Both pyrite and arsenopyrite occur as veinlets in the quartz. Mertie reports stibnite in the lode.

The lode in many respects is similar to that occurring on Goldbottom Creek. Two "runs of gold" are claimed for placers of Boulder Creek. Rough gold occurs below the point where the creek cuts the Boulder lode and is thought to be derived from the lode. The creek gold above the lode is fine and is assigned to the old stream gravels of the terraces that occur along the slopes.

The Lilly lode is on the saddle at the head of Twin Mountain Creek (fig. 19). Here a shallow trench at the limestone and schist contact exposes limestone cut by quartz veinlets and some iron-stained graphitic quartz schist. The limestone is somewhat silicified and shows decomposed pyrite in places, but no other sulphide was seen.

A few hundred feet west of this locality a 12-foot drift is run along a quartz vein in limestone. The limestone is an outlier on the schist and covers only an acre or so. No mineralized rock was seen in place, but a little mineralized quartz occurring in veinlets of ¼-inch size, closely spaced and parallel to the lamination of carbonaceous schist, contains pyrite, malachite, and probably chalcopyrite. The relations of these minerals to the country rock could not be determined.

Considerable placer gold has been mined on Pioneer Gulch, 2 miles north of Bangor Creek. Here the bedrock is not exposed, but Moffit has described the placers as being of residual origin. The alluvial gold is angular, and some of it is attached to quartz, indicating its source in the near-by bedrock. An old shaft on the creek bank is inaccessible, but to judge by the material on the dump it was opened on a quartz-calcite vein of the open-textured type, containing a little pyrite and arsenopyrite.

Last Chance Creek, where there has been considerable placer mining, is 2 miles northwest of Pioneer Gulch. Here Moffit noted the occurrence of scheelite. Near the mouth of Waterfall Creek, a tributary to Last Chance from the north, are exposed quartz veins which cut chloritic schist. The schist is highly folded, contorted, and fractured, and dips in general about 45° NE. Opaque quartz of the later-vein type containing a little pyrite occurs in veins from 1 inch to 1 foot wide along a shear zone in the schist. The zone strikes in general east and dips north. The quartz veins both follow and cut across the schistosity of the country rock. They are contemporaneous, as they do not offset or terminate one another but merge. This type of vein occurrence becomes prominent farther south in the Snake River valley. The Christophosen antimony lode, at the head of Waterfall Creek, has been described on page 231.

The California quartz lode is on Henry Gulch, a small tributary of Goldbottom Creek about half a mile from the Goldbottom-Mountain Creek divide. It is 20 miles north of Nome (fig. 19). The developments consist of a 70-foot shaft sunk on an incline of 60° and a 12-foot open cut in the creek bank. The shaft is said to have been sunk on the lode and to have left the lode at a depth of 33 feet. It was filled with water at the time of the writer's visit, and the lode was exposed only in the open cut. The property is equipped with a stamp mill having a theoretical capacity of 10 to 12 tons in 24 hours. Water power is supplied by a ditch 3 miles long, with intake on Fred Gulch. The mill equipment consists of a Blake Hercules jaw crusher, a battery of three 1,000-pound stamps, and a Pinder table. Most of the gold is recovered on the plates, the table having proved unsatisfactory, owing to sliming of the ore. No ore has been milled for several years, and the equipment is not in the best

state of repair. Practically no work has been done here since Mertie's visit in 1916. The lode occurs along a shear zone in the Nome schist, about 300 feet from the limestone area of which Mount Distin is a part. Mertie[80] describes the lode as follows:

The lode matter consists of shattered quartz and country rock, which are heavily iron stained and mineralized. The ore body lies along a shear zone, which has a general strike of N. 15° W. The shearing seems to have taken place along a number of faults, with this general strike and with variable dips to the northeast, but to have been concentrated along the hanging-wall side of the shear zone. The hanging wall is therefore marked by a well-defined fault, with slickensided walls. Below the hanging wall, for about 4 feet, the lode matter is greatly crushed, iron stained, and mineralized, and it is from this part of the lode that the ore has so far been taken. The footwall is not well defined, the lode merging gradually into the country rock on that side.

The country rock in this vicinity is chlorite and sericite schist, with considerable graphitic slate and some thin bands of limestone. These rocks contain a system of old quartz veins, which are parallel to one another and lie conformably with the cleavage of the schist, striking N. 40° E. and dipping 50° SE. The shear zone, which strikes N. 15° W., cuts diagonally across the quartz veins, and the character of the lode matter is therefore variable. At one locality it may be entirely the red, iron-stained shattered schist; at another it may be dominantly the mineralized vein quartz. * * *

The lode system is crosscut by the creek and well exposed. The mineralizing solutions were effective for a considerable distance laterally, for the iron staining is plainly apparent for 300 feet upstream from the lode and for a considerable distance downstream. The owner says that this zone of shearing may be traced 1 mile to the northwest and 2 miles to the southeast.

Pyrite and arsenopyrite are the principal mineralizing agents, but here and there a little free gold may be seen. In this as well as in most other gold lodes in the Nome district very little quartz has been introduced with the mineralizing solutions. Stibnite is reported to be present in seams 2 inches or less in thickness, but these were not seen by the writer. Hydrous manganese oxide is present in the gouge. Molybdenum and tungsten also are reported from assays.

The 4 feet of ore along the hanging wall is said to have a value of about $50 a ton, as indicated by assays, but the owner has been able to obtain only from $8 to $10 a ton from the plates. It is therefore inferred that much of the gold is either mechanically intergrown with the sulphides, in particles of microscopic or submicroscopic size, or chemically combined with the sulphides.

Several quartz veins 1 to 3 feet wide that crop out on the north side of the creek appear to be on the strike of the lode and a part of it. On the north bank, 75 feet west of the veins, a highly mineralized schist crops out which has no counterpart on the south bank. It is said that the fault surface of the lode has been traced along a sinuous course to this outcrop. Microscopically the rock is found to be a carbonaceous quartz-muscovite schist, containing considerable chlorite and a little sillimanite, zircon, and tourmaline. Sulphides are abundant.

Gold is said to occur throughout the mineralized schist of the lode. The schist is essentially a graphitic quartz-mica schist. Both mus-

[80] Op. cit., pp. 426-427.

covite and biotite are present, the latter largely altered to chlorite. Pyrite and arsenopyrite are plentiful.

No quartz ore was seen in place, but a sample of the better grade of gold-bearing quartz taken from the shaft was given to the writer. Microscopically the rock is seen to contain some oligoclase feldspar, and it is probably related to the quartz-feldspar veins. It includes considerable schist and in places is essentially schist cut by quartz. Free gold can be seen in the quartz. Arsenopyrite and pyrite are abundant, and apparently contemporaneous with the quartz. Stringers of quartz that cut the schist are of the later vein type but were not found to contain feldspar.

About 1 mile below the California quartz lode mine, on the west bank of Goldbottom Creek, a 60-foot tunnel is driven in chlorite schist. A small outcrop of quartz occurs above the tunnel, and several stringers of vitreous quartz showing a little pyrite are cut by the tunnel. No definite lode is apparent.

Two small tunnels have been driven and a shallow shaft sunk near the head of Goldbottom Creek on the south bank just above the forks. All the workings are now caved, and neither the lode nor the inclosing rock can be seen, on account of the cover of moss and earth. Some graphite schist, vein quartz, and mineralized siliceous rock, probably a silicified limestone, lie on the dumps, also some limonitic gossan material. There is no evidence upon which to judge concerning the size of the vein or its occurrence. No work has been done here for years, but work is said to have been in progress for a considerable time.

The most conspicuous and plentiful material on the dumps is the silicified limestone, in which considerable sulphide occurs. The rock abounds in openings into which well-terminated quartz crystals project. The openings are in general parallel, fissure-like, and discontinuous. Many of them are filled with calcite. Pyrite seems to be the only sulphide. It occurs in small isolated crystals, in nests, and in roughly parallel streaks. The sulphide does not fill the openings but occurs through the quartz. The rock is noticeably banded, owing in part to the open texture and calcite filling and in part to the arrangement of the sulphides. The quartz vein material indicates a vein of the later type. Openings occur in it, but no sulphide was observed. The schist is of a graphitic quartz variety in which the graphite occurs in distinct flakes. No sulphide was observed in the schist.

Two prospects which are somewhat north of the Nome district proper are of interest and will be described. One of them is on Buffalo Creek, a headwater tributary of Nome River, and lies well within the Kigluaik Mountains. The other is in Slate Creek valley, about 15 miles to the east.

The Buffalo Creek lode is on the west slope of the valley about 1 mile from the mouth of the stream. It is a quartz vein about 2 feet wide, strikes N. 45° E., and dips south. The vein follows a shear zone in schist of the Kigluaik group and ranges in dip from 45° to horizontal. The footwall is much sheared, but the nearest determinable wall rock is biotite schist. The vein is iron-stained quartz but shows no mineralization. A tunnel is driven in the soft, decomposed schist footwall for 20 feet parallel to the ledge but does not cut it.

The deposit on Slate Creek, staked under the name "Osmun lode," is described by Chapin [81] as follows:

> A prospect is being opened on Slate Creek, a small stream which flows into Kruzgamepa River from the south 4 miles east of Salmon Lake. The lode is a mineralized dike cutting greenstone. The rock is badly weathered, so that its original character is in doubt, but it appears to have been a fine-grained quartz-feldspar rock in which all the feldspar is now replaced by sericite and kaolin. The dike has been fractured and filled with ferruginous calcite that has partly replaced the included fragments and the walls. A later fracturing of the lode was healed by irregular veinlets composed of quartz and calcite deposited simultaneously. No assays of this lode were made, but small amounts of gold were obtained by crushing and panning the rock. The ledge, which is about 3 feet wide, strikes east and dips 70° N.
>
> A short distance south of the open cut mentioned is an outcrop of rock which appears to be another dike about 10 feet thick and parallel to the one described. It is an even-textured rock of gray color and very fine grain and, like the other dike, was probably a quartz-feldspar intrusive. Quartz, the only original mineral now found in it, occurs with a finely granular mass of epidote. Traversing the rock in many directions are irregular veinlets composed mainly of a green silvery micaceous mineral which proves to be chlorite. With it are associated a number of other vein minerals—quartz, albite, calcite, epidote, and a colorless amphibole which is probably tremolite. This dike is not thought by the prospectors to be of economic value, and work has therefore been confined to the other lode.
>
> The country rock is a fine-grained greenstone. It is evident that this was originally a basic igneous rock, but it has been entirely recrystallized. Green hornblende is the most conspicuous mineral, but considerable amounts of chlorite and epidote are present. Garnet and pyrite are abundant and may be readily seen in the hand specimen. Albite fills the interspaces and includes rutile and titanite and fragments of other minerals.

The Steiner lode is on the west side of Penny River about 4½ miles from the coast of Bering Sea, at an elevation of about 200 feet (fig. 19). Here a shaft has been sunk 105 feet and a drift run 220 feet N. 50° W. The shaft was started on a quartz-feldspar vein striking east, which is not now exposed. It is said to have been 5 to 10 feet wide and traceable for 1,000 feet on the surface. The quartz continued to a depth of 60 feet in the shaft and then dipped north. The shaft was continued 45 feet and a drift was run to intersect the vein but did not reach it. The quartz is said to have assayed $7 a ton in gold. The drift is run in quartz-mica schist and graphitic quartz schist.

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[81] Op. cit., p. 405.

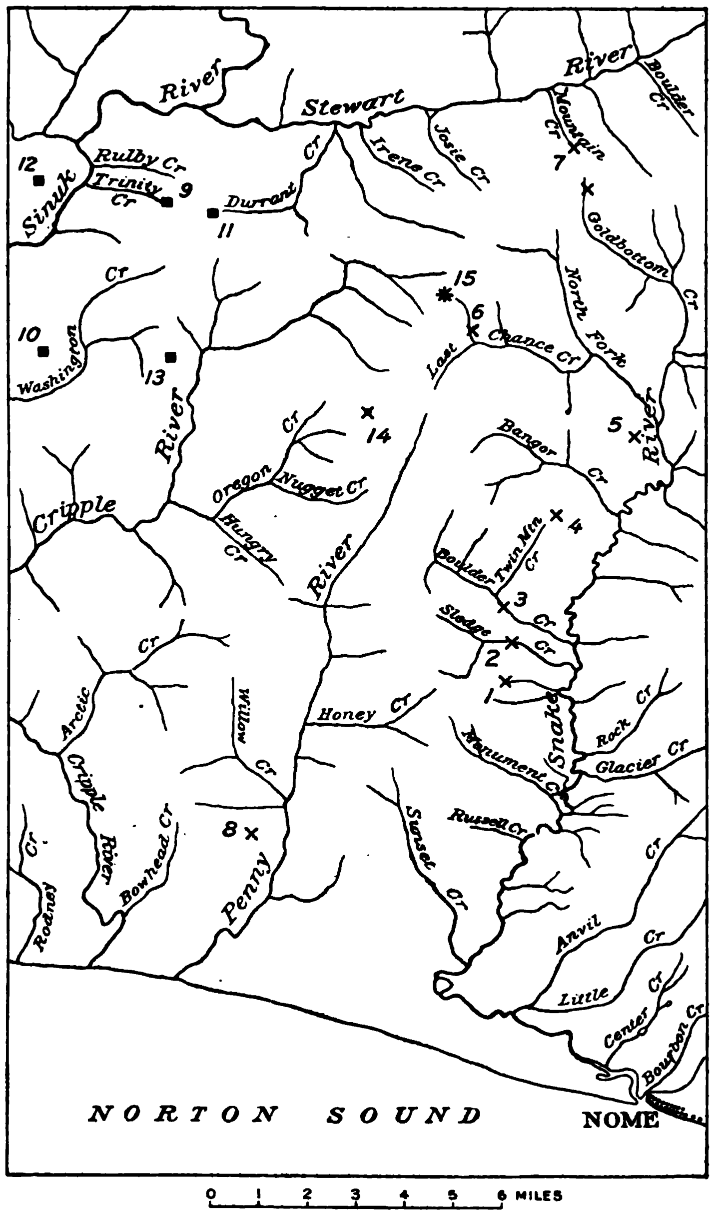

FIGURE 19.—Map showing location of metalliferous lodes northwest of Nome. 1, Alpha Creek; 2, Sledge Creek; 3, Boulder and Dakota; 4, Lilly; 5, Pioneer Gulch; 6, Waterfall Creek; 7, California; 8, Steiner; 9, Monarch; 10, Galena; 11, Mogul; 12, America; 13, Cub Bear; 14, 15, Christophosen.

The schist at the end of the drift strikes north and dips 45° W. A few quartz veins and several shear zones have been cut, but no definite lode has been encountered. The schist in places is highly mineralized and shows large cubes of pyrite. This material was said to be gold-bearing, but an assay made for the Geological Survey gave no returns for gold. Dust so covers the walls of the drift that little of the underground structure can be seen.

IRON DEPOSITS.

Several groups of claims have been staked for iron deposits in the upper basin of Cripple River and in the adjacent portion of Sinuk River basin. These are about 25 miles northwest of Nome (fig. 19). According to the reconnaissance surveys [82] the country rock of the region consists of schist, broken by belts of heavy limestone. The iron ore occurs chiefly in limestone areas. These deposits were first described by Eakin,[83] who made his examinations in 1914, soon after they were discovered. His work was supplemented by examinations made by Mertie[84] in 1916. Some additional notes were obtained by the writer in 1920. Eakin describes this general type of occurrence as follows:

> The iron-ore deposits consist of limonite veins and stockworks and their residual products. Hematite, galena, pyrolusite, and small quantities of gold also occur as accessories in some of the lodes. The examination was too brief to permit detailed studies, but the general impression gained is that there had been strong mineralization at certain localities, and that the mineralizing agencies had affected a considerable area.

The Monarch group of 15 claims appears to have had more development work done on it than on any of the others. Eakin states that this group covers a limestone ridge that trends eastward between Sinuk River and Washington Creek. He describes the deposit as follows:[85]

> It covers the ridge top for about 3,000 feet and extends laterally for over a mile. Within this property the ridge crest is broken by two gaps at an elevation of about 1,000 feet above sea level, in which are the chief deposits of iron ore. Elsewhere the limestone is more or less iron-stained and may contain small ore veinlets, but the average iron content of the limestone mass may be too low to permit its being classed as ore.
>
> The east gap is mantled by a heavy residual deposit of limonite and hematite, derived from the weathering of unusually abundant ore veins that cut the underlying limestones. The residual ores have also slumped down into the head of the gulch that leads northward from the gap, where they occur in considerable amounts. The veins in bedrock beneath the gap are apparently numerous and range in width from a

[82] Collier, A. J., and others, Gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pl. 10, 1908.

[83] Eakin, H. M., Iron ore deposits near Nome: U. S. Geol. Survey Bull. 622, pp. 361-365, 1915.

[84] Mertie, J. B., jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, pp. 444-446, 1917.

[85] Op. cit., pp. 362-365.

few inches to about 30 feet. They are approximately vertical, but their persistence, either vertically or horizontally, is not determinable from the exposures.

In the west gap there is no important accumulation of residual ore. The underlying limestone is cut, however, by a wide stockwork of limonite and pyrolusite veinlets. No heavy veins were seen at this locality.

The residual deposits of the east gap have been developed over an area approximately 600 by 800 feet, in open cuts that range from a few yards to several hundred feet in length. A shallow shaft and a short drift have been driven into the deposit in the head of the northerly gulch, 50 feet below the gap level. An open cut at the south margin of the gap has uncovered a mass of undisturbed limonite, apparently a vein 30 feet in width, cutting the limestone country rock.

In the west gap several short open cuts have been made in loosened bedrock material which contains numerous veinlets of limonite and pyrolusite. Elsewhere on the claims the iron-stained limestone detritus has been thrown out of open cuts without revealing any high-grade ores.

The residual ore of the east gap has a loose granular texture and a high iron content, and is unusually free from injurious impurities. Two samples taken by the writer, one from an open cut at the east margin of the deposit and the other a composite sample from a line of open cuts 400 feet long across its center, were found to contain 53 and 55 per cent of metallic iron, respectively. The complete analysis of the composite sample, which is probably fairly representative of the whole deposit, is as follows:

Analysis of composite sample of iron ore from Monarch group of claims.

[Analyst, R. C. Wells, United States Geological Survey.]

SiO_2	5.53	TiO_2	None.
Al_2O_3	1.34	P_2O_5	.13
Fe_2O_3	78.30	S	Trace.
MgO	.10	MnO	1.37
CaO	1.97	BaO	Trace.
H_2O	10.40		
CO_2	1.10		100.24

The iron, manganese, phosphorus, and sulphur contents of the ore, calculated from this analysis, are as follows: Fe, 54.81; Mn, 1.06; P, 0.057; S, trace.

No samples were obtained from the veins from which this residual material has been derived. The character of the ores in the undisturbed veins was therefore not determined.

Only qualitative analyses of samples taken from the west gap were made. They contain limonite and pyrolusite in about equal amount. The veinlets appear to comprise only a small part of the general mass of the stockwork, so that the iron and manganese content of minable material is probably not high.

The development work done so far on the Monarch property has failed to furnish an adequate basis for estimating the quantity of ore available in either the residual deposits or the underlying veins. The size and extent of the veins for the most part can only be conjectured. The area of the residual deposits is fairly well outlined, but their depths have not been generally demonstrated. However, it seems certain that the residual high-grade ores aggregate at least several hundred thousand tons. Apparently they cover an area 600 by 800 feet to a depth of several feet. In places shafts 12 feet deep are said to have been sunk in ore. Although ore occurs in the head of the northerly gulch 50 feet or more below the level of the east gap, it is unsafe to assume that the divide is underlain by ore to this depth, for this ore is apparently not in place but has slumped down into the head of the gulch from the gap above. Obviously additional prospecting will be required to determine accurately the reserves of

high-grade residual ores and to demonstrate the availability of the undisturbed vein ores. The stockwork of the west gap will also require careful investigation to determine its value. The relatively high manganese content of the veinlets and the reported association of gold with the manganese strengthens the possibility that this deposit may prove of commercial value.

The limestones on the property away from the gaps contain from 5 to 40 per cent of iron. The average content is probably nearer the lower figure, and if this proves true it seems doubtful that much of this material can be considered as commercial ore.

Mertie's interpretation of the facts available in regard to this ore body is in general accord with that of Eakin, but he has added some further details as follows:

The country rock is limestone, which has been brecciated and replaced by limonite. Hematite is present only as a subordinate constituent. A specimen of the ore taken from a trench at the head of Iron Creek shows on a polished surface massive limestone with numerous angular inclusions of iron-stained limestone, residual fragments of the shattered country rock. Pyrolusite, in places intergrown with calcite, is present in veinlets that cut the limonite and the replaced limestone. These relations and the probable genesis of this iron deposit will be discussed more fully in a later paper on the iron resources of Alaska. For this report it is sufficient to say that the iron ore now exposed on the ridge and in Iron Creek is a residual concentration, a surficial enrichment of an underlying lode. The iron content of this lode at depth can not be judged from the surface indications; in fact, it is entirely possible that this deposit is only a surface capping, or "iron hat," covering some other metalliferous deposit. The occurrence of galena and sphalerite with limonite in the Galena group near by, the presence of similar limonitic material in considerable amount in a silver-lead lode in the Inmachuk basin, and the constant association of limonitic material and other iron minerals with most of the gold lodes on the peninsula might be cited as evidence of this possibility.

Another group of claims has been described by Mertie [86] as follows:

The Galena group, consisting of nine claims, is about 2 miles southwest of the Monarch group on the divide between Sinuk River and Washington Creek. These claims, though prospected chiefly for their iron content, have also surface indications of both lead and zinc, in the form of galena and sphalerite.

It appears that the ore-bearing solutions have followed in large measure one or more of a system of joint planes in the country rock. On the Sunrise claim, one of this group, the country rock is crystalline limestone, the cleavage of which strikes east and dips 25° S. This limestone is cut by a number of joint planes, the more prominent of which had the following strikes and dips: N. 40° E., 65° NW.; N. 80° E., 70° N.; N. 15° W., 90°. Disseminated galena in a quartz gangue occurs along the vertical joint plane. This ore is said to show considerable values in gold.

An open cut on the Oso claim shows disseminated sphalerite, with a little pyrite, in the crystalline limestone. The extent of the zinc mineralization is not known. In a pit at another locality on the Oso claim the same system of jointing as above described was exposed, and vein quartz, with some iron-stained vein material, occurs along a joint plane striking N. 10° W. and dipping 75° N. Lilac-colored fluorite was also seen in this pit, but its exact relation to the mineralization could not be determined.

On the Fox and the Williams claims disseminated galena accompanied by quartz was observed in limestone and calcareous schist.

Considerable botryoidal limonite was seen on the dump at a prospect on the Kentucky claim.

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[86] Op. cit., p. 445.

The following description of the ore deposits of two groups of claims is taken from Eakin's report.[87]

The Mogul property consists of four claims situated on the Sinuk River and Washington Creek divide about 1½ miles east of the Monarch property. No development work has been done here, the locations being made on the strength of a few acres of the blossom of ore veins that cut the limestones locally. Evidence of the veins is found in heavily iron-stained limestone detritus that has a scant admixture of limonite nodules and vein fragments. There is little evidence as to the size and extent of the veins or the possibilities of commercial development.

The American group includes four claims situated at the base of a limestone ridge west of Sinuk River, below American Creek, 2 miles northwest of the Monarch property. The locations are said to cover an "iron-ore bed" over 50 acres in extent. The only development work done consists of a few pits 6 to 8 feet deep, and no analyses have been made of the ore. The locality was not visited by the writer.

The Cub Bear group of iron claims lies near the head of Cripple River on the divide between Cripple River and an eastern tributary of Washington Creek, at an elevation of about 1,000 feet. The developments consist of 12 trenches 20 to 30 feet long and 3 feet deep. The country rock is chiefly limestone, with a little interbedded schist. The mineralization occurred in a well-defined saddle between two knolls. The limestone of the eastern knoll strikes N. 10° E. and dips 15° E.; that of the western knoll strikes N. 10° E. and dips 20° W. Structurally the mineralization occurred along the crest of an anticline. The mineralized zone is exposed only by the trenches, as tundra covers the saddle. The trenches are alined about N. 5° E., which is approximately the strike of the country rock. Six openings are made on the north of the saddle, and six on the south. The trenches on the south expose limonite chiefly, with some hematite. The material is essentially iron-stained limestone, through which some small veinlets of iron oxide occur. The rock is badly fractured and seamed with incompletely filled veinlets of calcite. Only surface débris is exposed by the pits, and no rock of ore grade is seen on this side of the saddle. On the north side several of the trenches have exposed massive botryoidal limonite of good quality. A cellular limonite is also present on the dumps, and manganous oxide in small amount occurs with it. The quantity of ore on the dumps does not exceed a few tons. No ore in place is exposed.

The occurrence is very poorly exposed by the workings and elsewhere is covered by moss. Mertie reports sulphides to be present with the ore at the Mogul group of claims and suggests that the iron may merely be gossan material capping a sulphide vein. It is not possible to say whether this represents the gossan of a sulphide vein or not. No sulphide was seen. The zone of mineralization is probably 50 or 100 feet wide and, as observed, seems to occur along the shattered crest of a fold, which suggests that the iron oxide may be but a deposit resulting from the circulation of ground waters along this zone.

[87] Op. cit., pp. 364-365.

INDEX.

A.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

GENERAL.

REPORTS.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. No copies available. May be consulted at many public libraries.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4–9.

*The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39. 30 cents.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45 cents.

*The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62. 50 cents.

*The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20–46. 40 cents.

The mining industry in 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 21–42

*The mining industry in 1911, by A. H. Brooks. In Bulletin 520, 1912, pp. 19–44. 50 cents.

The mining industry in 1912, by A. H. Brooks. In Bulletin 542, 1913, pp. 18–51.

*The Alaskan mining industry in 1913, by A. H. Brooks. In Bulletin 592, 1914, pp. 45–74. 60 cents.

The Alaskan mining industry in 1914, by A. H. Brooks. In Bulletin 622, 1915, pp. 15–68.

The Alaskan mining industry in 1915, by A. H. Brooks. In Bulletin 642, 1916, pp. 17–72.

The Alaskan mining industry in 1916, by A. H. Brooks. In Bulletin 662, 1917, pp. 11–62.

The Alaskan mining industry in 1917, by G. C. Martin. In *Bulletin 692, 1918, pp. 11-42.

The Alaskan mining industry in 1918, by G. C. Martin. In Bulletin 712, 1919, pp. 11-52.

The Alaskan mining industry in 1919, by A. H. Brooks and G. C. Martin. In Bulletin 714, 1921, pp. 59-95.

The Alaskan mining industry in 1920, by A. H. Brooks. In Bulletin 722, 1921, pp. 7-67.

Railway routes, by A. H. Brooks. In Bulletin 284, 1906, pp. 10-17.

Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45-88.

*Geologic features of Alaskan metalliferous lodes, by A. H. Brooks. In Bulletin 480, 1911, pp. 43-93. 40 cents.

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